DISCOVERY

Monthly Notebook
DAVID S. EVANS
M.A., Ph.D., F.Inst.P.

The Story of the Potato
J. G. HAWKES
M.A., Ph.D.

Science in Canada
J. K. ROBERTSON
F.R.S.C.

How Reliable are Social Surveys?
J. GOLDMANN
B.Sc.(Econ.), F.S.S.

Hydrogen for the Balloon Barrage

Night Sky in March
M. DAVIDSON
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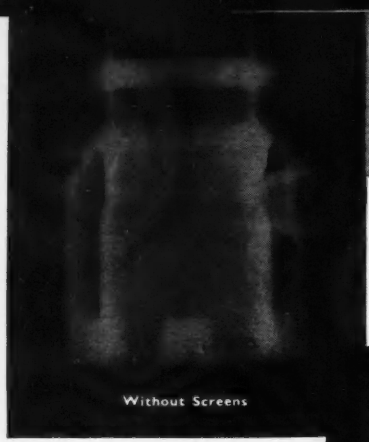

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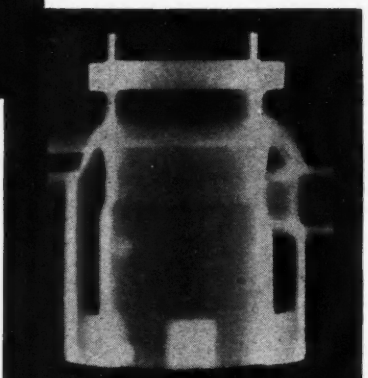

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

Frozen Soil

THE *Soviet War News* recently printed an account by Professor Obruchev of the scientific work being done in the region of eternally frozen soil in the north east of Siberia which includes parts of the basins of the great rivers Ob and Yenissei. Old-fashioned stories about Siberia would have us believe that these regions are perpetually frozen and inhabited only by Russians whose boots are laden with a snow that never melts however far they march. Comic-opera Russia however, is fortunately nearly dead. These regions are, in fact, comparatively fertile and well wooded, presenting a quite normal appearance on the surface. Only when the top soil is removed is the frozen layer laid bare. The greatest known thickness of this layer is recorded from northern Yakutia where it is over 1700 feet thick.

The existence of such frozen earth is something of a puzzle and the superficial notion that it must be something to do with the very cold winters is quite misleading. On numerous occasions, and in many parts of the world, measures have been made of the temperatures below the surface of the earth and of the sea. Both earth and water are comparatively bad conductors of heat with the consequence that the daily variations of temperature extend to only a few inches beneath the surface. What is more, the time required for the day-time heat or the night-time cold to reach any given depth means that the temperature changes which occur in the ground lag behind those on the surface, until at some depths the temperature will be highest when the surface is coldest.

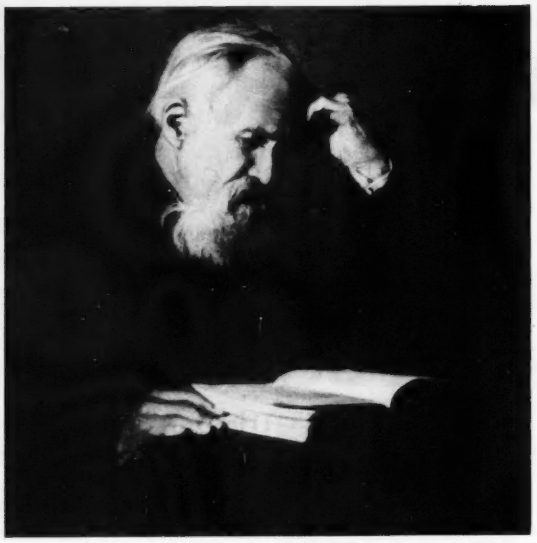
The same, of course, must be true of the yearly or annual variations of temperature as between summer and winter. Since the high summer temperatures are maintained for a long time and the cold lasts throughout the winter they will affect the soil temperature to a greater depth; but at quite a small depth—a foot or two, according to circumstances—the ground will be effectively insulated from the seasonal variations in surface temperature. The same time-lag will make itself felt; at quite a small depth the temperature fluctuation will be greatly reduced, and the slowness of the heat flow through the soil will mean that when it is winter on the surface a much toned-down version of last summer will be happening some way beneath.

The perpetually frozen layer cannot be due to the winter cold, which does not penetrate deep enough. Only a long continuous period of cold could produce it. To look at the matter another way, if there is some great meteorological rhythm taking place with a slow oscillation occupying hundreds of thousands of years, then, as greater depths are reached, there must come a level at which the climatic conditions of the distant past are unearthed.

This, it is believed, is the explanation of the eternally frozen soil. A yard beneath the surface brings the digger to conditions in the past corresponding to the end of the last ice age; still deeper layers have remained frozen, reflecting in their frigidity the age-long cold which once enveloped the earth and reached as far south as the Thames. Since the ice age ended the mild climate has caused a steady recession of the frozen layers, which in some places are found still to be receding, at the rate of about sixty miles a century. In regions where perpetually frozen layers are encountered, the ground above them reflects the thermal history of post-glacial times, and in this soil, which has thawed relatively recently, pines and other coniferous trees grow.

Those are the conditions in undisturbed land. But if the frozen layer is exposed it melts. If buildings are built in the ordinary way, with trenches for their foundations dug so as to expose the frozen layers, the heat from the dwellings melts the ice and the ground becomes a quagmire into which the buildings settle and collapse. This has happened to railway workings such as those of the Transbaikal Railway which was built in 1898 and began to suffer only two years later; after ten years the foundations were completely thawed and the buildings became stable once more.

The Institute for the Study of Frozen Soil, founded in 1939 and now called after Obruchev, has developed special building techniques to get round these difficulties; for instance, piles are driven into holes, thus avoiding the exposure of any part of the frozen ground, and this has been most successful.



Academician Vladimir Obruchev

Heat however is not the only means of melting ice; pressure will do it too, as is well known to the maker of snowballs who freezes his snow into coagulated lumps by pressing it in his hands. The same effect is used in skating when the skate blade produces a high pressure beneath its narrow edge and by melting the ice creates a water cushion on which motion is made easy. This melted ice freezes again as soon as the pressure is removed. Some of the greatest difficulties encountered in the frozen soil region come from this effect.

When winter sets in, a layer of ice is formed in the top layer of the soil. Beneath this comes a layer of normal soil containing water, and below that lies the layer of eternally frozen soil. High pressures are set up by the freezing of the top layer and transmitted to the water in the intermediate layer which is thereby prevented from freezing although it is below zero centigrade. This water flows through the soil until it reaches an outlet, which may often be the melted topsoil in and around a house. There it wells up and, with the release of the pressure, freezes instantaneously. This is the reason why old houses built by ordinary methods often present the fantastic sight of frozen cascades bursting out of the windows.

Yet other difficulties arise as the result of road building. The roads are cleared of snow, which is a good heat insulator, and the winter frost freezes the road to a considerable depth, forming a sort of underground ice dam. This stops the subsoil water, which wells up over it and freezes, producing a huge ice hummock and rendering the road impassable. The remedy is to dig a snow-free ditch alongside the road and this, on freezing, produces the ice hummock to one side of the road. A natural hummock of this kind, 16 miles long, 4 miles wide and is 4 yards thick, has been found on the river Moma.

Where it is desired to thaw the soil, the mosses, which form an excellent insulator, and a trap for dew and subsoil water, are removed, but in most cases it is best to leave the soil frozen and to adapt building and working conditions to it.

Quite apart from these purely practical aims the subsoil conditions of these strange regions will obviously enable much information to be gained about climatic conditions in the distant past; history can be read by digging, just as the examination of annual deposits in Swedish lakes has yielded information about the climatic variations of the past.

Something about Earthquakes

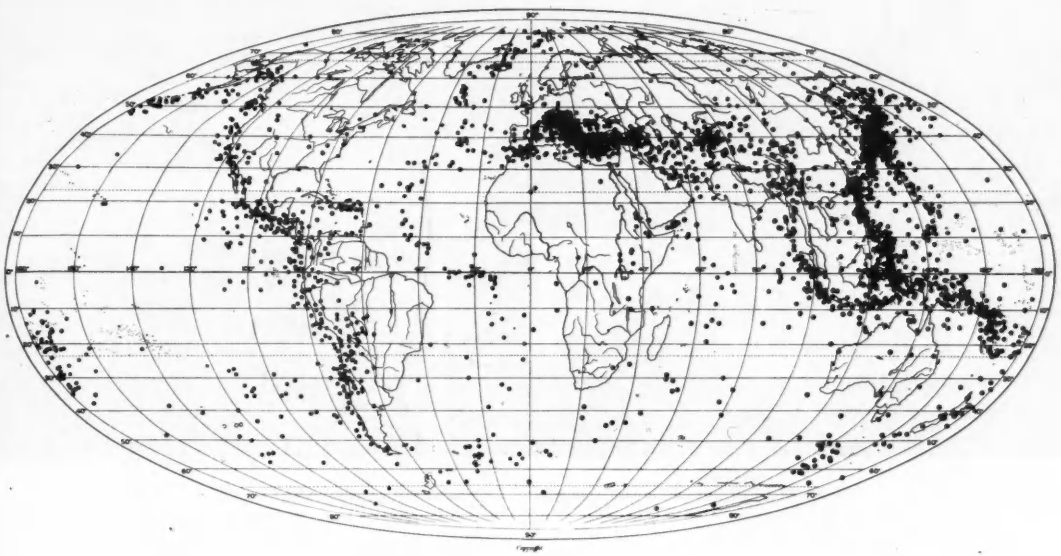
THE earthquake which occurred in the north of England on December 30, 1944, provided a topic of conversation almost as fruitful as the bomb-stories of the blitz but fortunately, as the accompanying chart shows, earthquakes in Britain are comparatively rare; 68% of all earthquakes originate in a belt running round the Pacific Ocean and making almost a complete circle, although it appears on the map in two halves; 21% occur in the Mediterranean region, while most of the rest occur apparently at random, though there are smaller concentrations along a line running down the Atlantic from Spitzbergen, and to a still smaller degree down the Nile and Great Rift valleys in Africa.

Earthquakes are very often associated with regions of comparatively rapid geological change, as for example steep high mountain chains which have not yet been weathered down. In particular they are the result of earth movements which occur at geological faults. At a fault the strata are cut across, and the rocks on one side may be displaced vertically, obliquely or horizontally with respect to those on the other side of the fault. Occasionally the rocks on one side, under the action of tremendous pressures, will slip, and the resulting waves of disturbance propagated through the earth's crust and core are what we know as an earthquake. It sometimes happens that the forces tending to produce these earth movements may impose a stress on the rocks just insufficient to cause slipping, and then the earthquake may finally be precipitated by some quite small cause such as a high tide of a second distant earthquake.

Over the whole world, major earthquakes, which would cause great destruction if they happened in populated regions, occur about once a fortnight while small ones occur every few minutes. Earthquakes in Britain are rare, but when they do occur they are associated with geological faults such as the Great Glen Fault near the Caledonian Canal and the Highland Border Fault between the Grampian mountains and the Midland Valley of Scotland.

Earthquakes mostly occur on the outer side of mountain and island arcs (especially those with steep slopes) and are therefore often not immediately associated with volcanoes which occur mainly on the inside of such arcs.

A scale for describing the intensity of earthquakes is the Mercalli scale which is based on the maximum acceleration of the earth's surface experienced. If an object is allowed to fall it experiences an increase of velocity (acceleration) of 32 feet per second in each second; in metric terms, the speed after one second will be 981 centimetres per second, after two seconds twice that figure, and so on. The human frame is readily conscious of far smaller accelerations, and the sinking feeling experienced in lifts or on board ship is



Origins of Earthquakes during the years 1913-1930. Map by Stamford Ltd.

the result of accelerations which are only a small fraction of that due to gravity.

The mildest earthquakes, which require instruments for their detection, produce an acceleration of only one cm. per second per second, i.e. 0·1% of that due to gravity. This is classified as I on the Mercalli scale, and we must go up this scale as far as grade V, corresponding to an acceleration ten times as great, before the earthquake is strong enough to wake sleeping people. At VII, with accelerations of 50 centimetres per second per second, we come to strong earthquakes capable of cracking walls. At IX, with 250 cm./sec./sec. or one quarter that of gravity, houses fall, while at XII the accelerations are greater than that of gravity and are therefore sufficiently large to throw objects into the air; here we reach the top of the scale, with catastrophic earthquakes which produce total destruction and leave the ground badly twisted.

In an earthquake, waves pass through the ground which lifts and falls like the waves or ripples of the sea, cracking and fissuring as it does so. Vibrations of only $\frac{1}{1600}$ in. can be felt and waves of ½ in. would wreck ordinary buildings. It is clear that the north of England earthquake was a mild affair and not to be compared with such upheavals as the Assam earthquake of 1897 when vibrations of nearly one foot in amplitude occurred at the rate of 200 a minute; the Tokyo earthquake of 1923 when Oshima island was moved by a distance of 12 feet; the Alaska earthquake of 1899 when rocks were thrust up by upwards through a distance of 47 feet, or the 1906 California earthquake when the ground underwent a lateral shift of 21 feet.

These are some of the most violent earthquakes ever experienced. When such disturbances take place, landslides occur, glaciers move and, below the sea, deposits of mud may be sent slithering down the continental slopes to change the ocean's depth by perhaps a thousand feet in places and to set up huge tidal waves which, like the one 40 feet high that occurred at Lisbon in 1755, can wreak immense destruction.

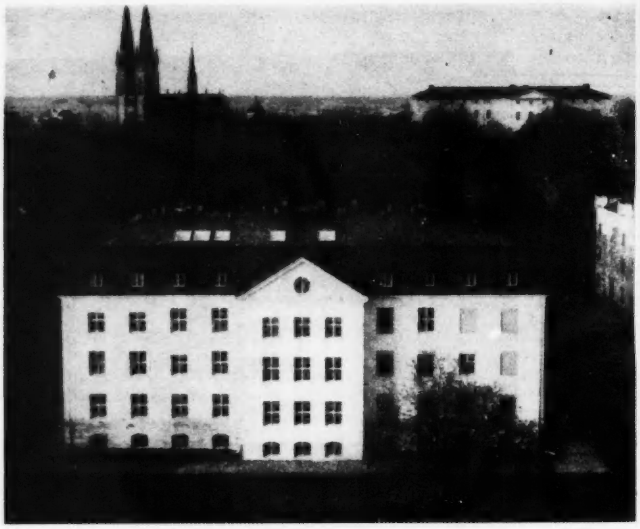
Fortunately for us, the old and stable strata of Britain are not subject to such violent movements, though we occasionally experience minor earthquakes which hardly startle a population all too familiar with loud detonations.

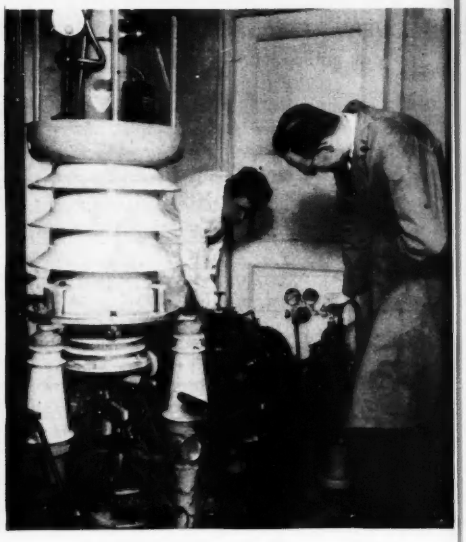
The Svedberg and the Ultra Centrifuge

SWEDEN has produced many able scientists, probably a greater number in proportion to her population than many larger nations. They include, for example, Linnaeus, who founded systematic botany; Angstrom, the physicist who has given his name to the unit of length used in spectroscopy; and Ekeberg, the chemist who discovered the metal tantalum. By the variety and power of his work, Professor The Svedberg of the Institute of Physical Chemistry at Uppsala is worthy to rank with the greatest of his fellow-countrymen.

The Svedberg reached his sixtieth birthday last August and, in accordance with a charming custom more often honoured on the continent than here, his pupils and colleagues have combined to produce a volume of scientific papers and biographical essays as a tribute to the great scientists.

The present Institute of Physical Chemistry at Uppsala is a comparatively new building put into use in 1931. When, in 1912, Svedberg was appointed to his "persona





(*Left*) The Institute of Physical Chemistry, University of Uppsala. (*Right*) The Institute's neutron generator, used in producing radio-active isotopes.

professorship" (i.e. one not involving elementary teaching duties) he worked in the university's old chemical institute that had been built in 1904. There he carried out his classical experiments on colloid chemistry, that is, the chemistry of materials in which one substance is dispersed in the form of fine particles, droplets or bubbles throughout another. Such systems are of increasing importance; they include, for instance, dust particles dispersed in air, and oil broken up into droplets and dispersed in water or some other medium, as well as dispersions of solid particles within a solid, and of gas bubbles throughout a solid or liquid. His work also included the investigation of liquid crystals and of the fundamentals of the photographic process.

However, Svedberg's name is most closely associated with the ultra-centrifuge, the principle of which can easily be understood, although the technical details of its construction immediately lead one into some of the more advanced regions of engineering and optics. Swing your lettuce round your head in a cloth to dry it, say the expert salad makers, and dry it does become because the pull of the cloth keeps your lunch continually changing its direction of motion and moving in a circle, while the unwanted water travels in a straight line and leaks out to form a series of drops deadly to the bystanders. To put the matter another way: if one were a lettuce leaf one would be supported by the cloth, but the water in which one's salady framework had been washed would be drawn outwards, that is to say, to the lettuce leaf there would be apparently a very strong force of gravity which drew away any object free to move.

The pilot of an aircraft in a tight turn is in the same situation as the lettuce leaf. He feels very heavy because the floor and seat are pressing inwards and forcing him into the turn but his blood is not so supported and becomes, so far as the pilot is concerned, three times as heavy as before. To an outside view the source of this extra force is the centrifugal force of the turn, but both views of the matter are equivalent; like the water off the lettuce, the blood of the pilot runs outwards –in this instance, down towards his feet—and, if the turn is too sharp his brain is deprived of blood and he experiences a black-out. A less war-like example is the form of entertainment (which is quite safe because it depends on very simple physical laws) known as the Wall of Death.

Centrifugal force has been employed in the laboratory for many years. The centrifuge is simply a small rotor on which a number of tubes can be mounted in hinged supports. The tubes are first carefully balanced, if necessary by filling a blank one with the proper quantity of water, and are fitted into the supports. When the rotor spins the tubes fly out almost to the horizontal, and become subject to what is, in effect, a gravitational field very much stronger than the normal. In this way materials dispersed in a liquid medium, such as a fine powder in water, can be rapidly separated. In the normal gravitational field sedimentation might take many hours, but in a field several times as powerful, sedimentation may be completed in a matter of minutes. Centrifuges of this simple type, with speeds of up to several thousand revolutions per minute, are in general use, especially in biological laboratories where, for example, they can be used for separating the solid material in blood from the watery components.

The ultra-centifuge has a rather different purpose. It works at far higher speeds—60,000 revolutions per minute or more—and produces a far higher gravitational field. It has found special application in analysing complicated biological mixtures into groups of molecules of different molecular weight. Usually the separation is not a permanent one in the sense that the various types of molecule can, after centrifuging, be handled separately. It takes place only when the material is being spun, and the different layers formed under these conditions correspond to

(*Above*) Professor Svedberg with his wife, who is seen preparing the rotor of an ultra centrifuge. (*Right*) Professor The Svedberg.

different molecular species. This differentiation is observed optically and the differences of distribution from the inside to the outside of the cell, which in this case is put into a longitudinal hole machined in the rotor, can be recorded photographically.

The ultra-centrifuge has proved a weapon of great power in the investigation of molecules of very complex substances, and progress has been made which would have been impossible by other methods. It is with the ultra-centrifuge and the investigation of large molecules that Svedberg's main work has been associated. The idea of the ultra-centrifuge took shape in 1923 when, as visiting professor to the University of Wisconsin, Svedberg worked with J. B. Nichols. The first efficient ultra-centrifuge was made in 1924 on his return home and was used for the investigation of proteins. Svedberg was awarded the Nobel Prize in 1926.

For the budget year 1927-28 he persuaded the University of Uppsala to secure a grant of 1,200,000 Swedish Crowns in the Parliamentary estimates, to be used for the building of the Institute of Physical Chemistry. This was scientifically designed by Bjbörnstahl, a collaborator of Svedberg's who made a special study of laboratory design, the result being almost the best designed and equipped physical chemistry laboratory in the world. It has a first-class workshop where centrifuges have been built for laboratories abroad. It has a computing department employing a staff of seven, and the whole institute includes nearly a hundred workers. The organisation is along industrial lines, the research workers taking their samples to the centrifuge operators who pass their records to the computing department for analysis. This feature is of especial value to the many visiting workers from overseas who would otherwise have to spend far too great a proportion of their time learning the techniques of machine operation and calculation.

Svedberg has given valuable scientific assistance, especially since the war, to an extraordinary variety of Swedish industries ranging from cellulose, rayon and plastics to brewing and photography, and he initiated production of synthetic rubber at the pilot plant level in his own institute.

The personal details of Svedberg's life are not without interest. His photographs show a Viking of a man who looks far less than his sixty years. Photographs published in the commemorative volume show him and his friends on social occasions from student days onwards, and the picture of a "Pokerafton" shows that not all his evenings were spent thinking of colloids. One gains the impression of a personality, amiable as well as vigorous, as indeed he must be to hold together the great scientific organisation which he has built up. Finally there is an amusing little note concerning his Christian name, which English and American correspondents have thought to be similar to such titles as "The Macintosh of Macintosh", so that letters have been addressed and delivered to "the Svedberg, Uppsala, Sweden". In earlier days there might have been some uncertainty, but now his fame is so secure that Swedish postmen can have no doubt as to who is intended.

REFERENCE:

"Something about Earthquakes": *Principles of Physical Geology*, by Arthur Holmes, (Nelson).

FIG. 3.—Making chuzo. The potatoes are being trampled by Indians to press out the juice.

The Story of the Potato

J. G. HAWKES, M.A., Ph.D.

FEW people give a thought, when eating a potato with their mid-day or evening meal, to the remarkably varied and interesting history of this seemingly unromantic vegetable. The potato is taken for granted to such an extent that one finds it difficult to imagine a state of affairs in which it plays no part in our dietary. Yet 400 years ago it was quite unknown to Europeans, and even then, for more than a century after its introduction, it was regarded in most countries as a botanical curiosity rather than as a food plant. Only in Ireland and Italy was it generally accepted; in the rest of Europe the eighteenth century was well advanced before it became the staple crop plant that we know to-day.

The Spaniards found the potato in the mid 16th century in the South American countries that are known to-day as Colombia, Ecuador, Peru and Bolivia. Later in the century they found it in Chile also. Beyond mentioning its growth and cultivation, however, they gave it scant consideration, being far more interested in finding treasure and in winning converts to the Catholic faith. Yet it has been calculated that the world potato crop in a single year has a value exceeding that of all the gold, silver and precious stones that the Spaniards exacted from their fabulously rich empire during the several centuries that it lay under their domain.

The first mention of the potato was made by Castellanos in the year 1537, when he was on a military expedition to the Magdalena valley of Colombia. He likens it to the truffle, and many later writers found the same simile appropriate. Later, in 1550, the famous chronicler Pedro Cieza de León saw the potato at Quito in Ecuador and in the highlands of Peru. The chronicle of Fray Antonio Vásquez de Espinoza, *Compendium and Description of the West Indies*, written in 1628 or 1629 and only recently discovered, also frequently mentions potatoes, known to the natives as "papas", from various parts of the Andes. This name, *papa*, seems to have been generally used throughout the Andes, whilst our own word "potato" has been derived from the word "batata", applied originally to the sweet potato although this is an entirely different plant. Gradually, however, the word "potato" was used more and more to signify the common potato, while the word "papa" is now only in use in South America.

Inspite of the frequent mention of the potato as a plant cultivated by the highland Indians of South America at the time of the Spanish conquest, 18th and 19th century savants consistently regarded the European potato as having been brought over in the form of a wild plant, and cultivated only in Europe. From the accounts already mentioned it can be seen that this was quite wrong adn that the potato must have been very widely cultivated in the Andes. Furthermore, it is also evident from later accounts that many cultivated and wild species of potatot occur in South America in addition to the type broughe to Europe, which we know as *Solanum tuberosum* L. We shall therefore begin our discussion of the history of the potato with an account of its growth and culture before the Spanish conquest.

At the time of the conquest the South American Indians of the Andes mountains were ruled by the imperial dynasty known as the Incas. Their empire stretched from South Colombia, through Ecuador, Peru and Bolivia to

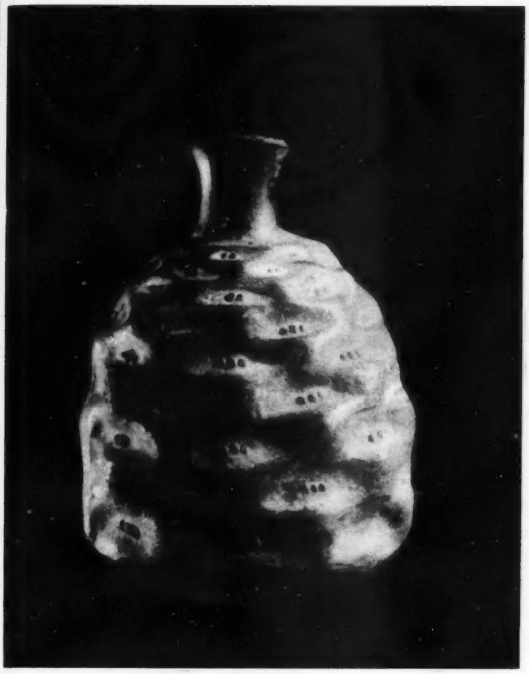


FIG. 1.—A "potato pot" from the Peruvian coastal deserts, probably of late Chimu type. FIG. 2.—The tuber of a South American potato grown in Britain last year, exhibiting a distinct resemblance to the pot.

the northern regions of Argentina and Chile. It also included the Pacific coastal belts of these countries, but did not extend any distance into the Amazon basin. (In Colombia, the region around Bogotá was a minor empire ruled over by the Chibcha Indians, while in the coastlands of South Chile and the island of Chiloé the Araucanian Indians held sway).

Record in Pottery

Although the potato was cultivated within these three empires the history of its culture in the two latter domains is not known very clearly. The Incas, however, were only the last representatives of a number of cultures both in the highlands (Tiahuanaco type) and on the Pacific coastal deserts (Chimu and Nasca types). These latter peoples pre-dated the Incas by a considerable time and were eventually conquered by them. It is probable that they did not cultivate the potato themselves since it will not grow well at sea-level in the tropics. It is certain, however, that they must have obtained it through trading with the highland pre-Inca, Tiahuanaco peoples, since it is pictured frequently on their ceramics. The art of writing was never discovered by the New World Indians so that no written records exist to simplify the search for such historical details. Nevertheless the Nascans and Chimus left very detailed records of their everyday life in their pottery, fabricating many pots in the form of potato tubers (Fig. 1). These "potato pots" are known to us from levels that have been dated at about the second century A.D., and extend right through to the Inca period. Since the earliest known potato pots are of a highly symbolic type, it is reasonable to suppose that the potato was, even at that time, a very ancient crop plant. The pot represented in Fig. 1 is fairly accurately representational, and is probably of late Chimu type. It can be compared with Peruvian potatoes of the present day (Fig. 2), which are seen to be very similar.

Many of the 16th and early 17th century chroniclers mention a certain method, very prevalent in the Andes of Peru, of drying and storing the potato. Thus Acosta in his *History of the Indies*, published in 1588, writes: "*The Indians use a kind of roots which they call papas. These roots are like unto ground nuts; they are small roots which cast out many leaves. They gather this papas and dry it well in the sun, then beating it well they make it into what they call chuna.*"

Chuña, or chuño as it is now called, besides being made widely at the present day in Peru and Bolivia, has been found, perfectly preserved, in ancient tombs and in temple and city storehouses, thus affording additional evidence of the esteem in which the potato was held and of its wide and ancient distribution among the Indian tribes of the Andes and adjacent regions.

The making of chuño involves spreading potatoes on the ground in a thin layer in high, cold places where the most severe frosts are to be expected. After freezing all night the potatoes are trampled by the Indians in the early morning (Fig. 3) with the object of pressing out as

much juice as possible from the cells, the walls of which have been broken by the frost. The moistureless winds and brilliant sun complete the drying process, rendering the tubers capable of storage for an indefinite time.

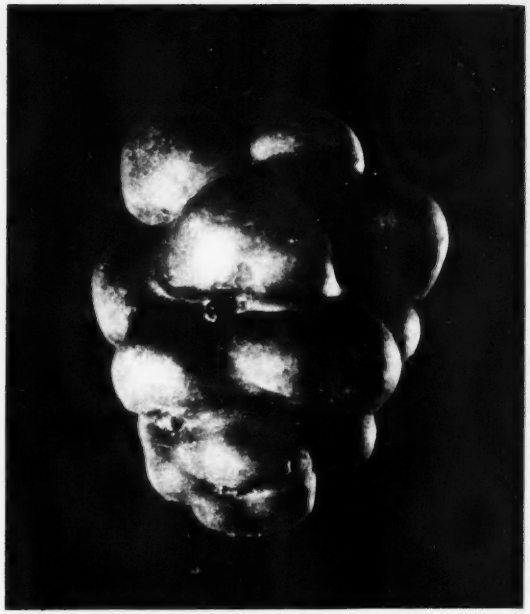
Unfortunately, it would not be possible to copy this process in Britain, since the secret of success lies in the quick drying that results from the combination of very dry mountain air, brilliant sun and sharp night frosts. Chuño is normally grey in colour, but a superior white brand known as "tunta" or "moray" is produced by washing the tubers in a stream for a fortnight after the trampling. Tunta, which is composed of pure starch, is said to command very high prices, though the present writer found both chuño and tunta very little to his taste! Both sorts are commonly used in soups by the highland Indians and form a great standby in years of crop failure.

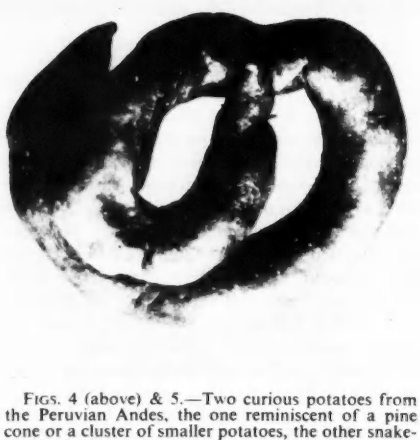
Bizarre Shapes and Colours

At the present day, as in the times of the conquest, potatoes are widely grown in the Andes of Colombia, Ecuador, Peru, Bolivia and North Argentina, and on the coastal plains of southern Chile. The Indian cultivators possess stocks exhibiting a great variety of bizarre colours, shapes and textures. Many of their potatoes have red or purple skins, generally possess deep eyes and are often very "lumpy" as Fig. 4 shows. Besides the round and oval ones, there grow also long, spindle-shaped types; others, by reason of their long, deep eyes, look like concertinas, and still others remind one of worms or snakes (Fig. 5). Many varieties also have flesh tinted red or purple, whilst one well-liked Peruvian sort has deep yellow flesh and is of very fine flavour. A certain variety known to the natives as "Chapiña," is jet-black all through and is used for dyeing cloth. (This type, it is interesting to note, was mentioned by the Jesuit Bertonio, in his dictionary of the Aymará language, published in 1612). Most of the native potatoes are given distinct names in one or other of the two Indian languages, Quechua and Aymará, and the names usually refer to the qualities of shape or texture, colour or eating quality.

It is very noticeable that the number of potato varieties grown in the central Andes of Cuzco and the Lake Titicaca basin is exceptionally high; the number of species also is greater here than anywhere else. Modern genetical theory indicates that the origin of a crop plant is located in that region where the largest amount of variation occurs. The Cuzco—Lake Titicaca region would therefore seem to be the centre of origin of the cultivated potato (Maps 1 and 2), and this conclusion is also supplemented by the archaeological fact that this area is probably the cradle of the ancient Peruvian civilisations. No doubt the earliest agriculture in South America had its origin here and was based on the culture of the potato and other tuberous crops, whereas maize was probably not brought into cultivation until later. (Whether the latter point is so or not, it is evident that maize culture never supplanted that of the potato in the high Andes, since the altitude and the climate, though suitable for the potato, are respectively too great and too rigorous for the cultivation of maize).

We have considered briefly the history of the potato in its native home, its antiquity as a crop plant and the general





FIGS. 4 (above) & 5.—Two curious potatoes from the Peruvian Andes, the one reminiscent of a pine cone or a cluster of smaller potatoes, the other snake-like in shape.

esteem in which it was held. It now remains to discuss the story of its introduction and history in Europe.

This is a problem of great difficulty, since we not only have to decide when it was introduced, but from what part of South America and to what part of Europe. We also need to know what kind of potato was brought over, since, as we have already mentioned, there are a large number of cultivated species of potato existing in hundreds of different varieties.

In the first place it is quite certain that there were at least two separate introductions, the first into Spain in about 1570, the second into England a few years before 1596. The evidence for this statement is extremely

complex; nevertheless it will be of interest to outline it in the present account.

In his *Phytopinax*, published in 1596, the herbalist Caspar Bauhin gave the potato its scientific name, *Solanum tuberosum*, though in his later works he added the adjective *esculentum*. Bauhin also gave the plant its first botanical description. He obtained his specimens from a supply that the celebrated botanist Clusius had received from Philippe de Sivry in 1588. De Sivry was given the potatoes by a friend of the Pontifical Ambassador in Belgium, who himself had obtained them under the name of "Taratoufli" (truffles) from Italy.

Several contemporary references indicate that the potato was commonly grown in Italy at that time and had been brought there from Spain by the Carmelite Friars. Dr. R. N. Salaman[1] has found references to the potato having been grown in Spain in about 1570 to 1573, and we may fairly safely place the date of its introduction into that country at about 1570; and since it was not known in other European countries until much later than this date we may conclude that it was first introduced into Spain, especially since the Spaniards controlled all the trade with their American colonies. No account is known to exist which gives the actual date amd mode of introduction, though we know fairly certainly that it had not arrived there by 1564, for in that year Clusius travelled in Spain collecting plants and notes for a treatise on the flora of that country but made no mention of it. Our knowledge of the work of Clusius is such that we can be quite certain that he would have referred to the potato had it been growing in Spain during his visit. We can, therefore, only say that it was first brought to Europe between the years 1564 and 1573, and most probably in or about 1570. We shall deal later with the theories put forward to deal with its place of origin, and shall content ourselves here with remarking that the potato was probably brought to Spain as ships' stores with little or no thought as to its potential value to Europeans.

The second introduction of the potato into Europe was mentioned by John Gerard in his *Herball* of 1597. This plant was brought to England and is quite definitely not the same variety as was described by Caspar Bauhin and Clusius, since the tubers were light-brown, whereas those of the continental herbalists were distinctly reddish. An illustration of Gerard's plant, taken from his *Herball*, is reproduced in Fig. 6.

FIG. 6.—An early illustration of the potato in Gerard's *Herball*, published in 1597. (Reproduced from *Herbals* by kind permission of the author, Mrs. A. Arber, and the Cambridge University Press).

Gerard confused the whole story for 350 years by blithely stating that his potato came from Virginia, the new British colony on the east coast of North America. It is only quite recently that this statement has been proved to be entirely erroneous. No potatoes, either wild or cultivated, were known in Virginia until 1621, when two chests were sent there by the Governor of the Bermudas. (These latter potatoes had, in any case, been derived from English-grown stocks in the first place). Gerard was apparently so interested in his potato that he had a portrait of himself holding a sprig of the plant engraved on the title page of his herbal. It is known that Gerard's reputation for accuracy, even among his contemporaries, was not too high, and we must therefore presume that he had confused the potato with some other tuberous plant from Virginia. We know that the scientist Heriot, who returned from Virginia in 1586, brought with him a collection of plants from that country, and it is fairly certain

[1] The Potato in its Early Home and its Introduction into Europe. *Journal of The Royal Horticultural Society*, 1937: 62; pp. 61 to 77, 112 to 123, 153 to 162, 253 to 266.

FIG. 7.—*Solanum tilcarense*, a wild potato growing flattened to the ground in the high Andes of northern Argentina.

that he showed these to Gerard. The potato might have been brought over by some other voyager at about this time, though not earlier than 1581, since Clusius visited England in that year and would have mentioned the fact in his own herbal if the potato had been known in England then.

Heriot was brought back from Virginia, together with Raleigh's unsuccessful colonists, by Drake who had previously been sailing along the north coast of South America. It has been suggested that in his raids on the Colombian coastal towns he obtained potatoes as stores or loot. We know that he raided Cartagena, which is the port for Bogotá where potatoes were, and are still, grown in considerable quantity. Potatoes were certainly brought to Cartagena to be stored aboard Spanish ships that were returning to Spain. What more natural, therefore, than that Drake should have obtained potatoes in this way, and that they should have been shown to Gerard at the same time as the Virginian plants that had been brought to England in the same ships? We have no documentary proof for this, it is true, but it does explain the various anomalies in the story reasonably well. The year 1586 is, therefore, generally assumed to be the most likely guess, though we cannot be exact about the years between Clusius' visit in 1581 and the publication of Gerard's garden list in 1596, in which the potato was mentioned for the first time in England.

The English potato was taken to Ireland where it was quickly accepted, legend attributing the introduction to Raleigh in about 1587. The facts are scanty but at least do not contradict this assumption; certainly quite a large amount of evidence has been found in recent times to support this hypothesis put forward by Dr. Salaman (in his paper in the *Journal of the Royal Horticultural Society*, already referred to), and it is known that it was a market crop by 1623. In Ireland, largely due to the impoverished nature of the peasantry, it was quickly accepted and grown widely, whereas in England, with its higher standard of living, the vegetable remained a botanical curiosity or a rare delicacy for the Royal table. Towards the end of the 17th century, however, it began to be widely grown in Lancashire, where it had been introduced from Ireland.

In Scotland, religious prejudice militated against its use since no mention of it was to be found in the Bible; in fact, it was not cultivated there until 1683, and did not reach the highlands and isles until 1743.

The history of its spread in Europe is similar to that in England. In France it was not until the mid 18th century, and even then largely due to the efforts of Parmentier, that it became at all popular. The famines and distress consequent upon the social upheavals of the Revolution also helped greatly to break down prejudices and popularise its cultivation.

Summing up its later history in Europe, one can hardly escape the conclusion that the potato when first introduced was a crop that could not hope to compete with those already in use, except in such countries as Ireland where the standard of life was so low as to admit of the potato being a definite improvement on the existing diet. Only later, presumably when it had been improved by selection, could it compete with the crops already in use and take a leading part in the dietary of the people.

Breeding Hardier Varieties

We should be fairly safe in stating that the modern phase of the potato started at about the beginning of the 19th century. At this time it had become firmly established in most European countries, and scientists were beginning to take an interest in finding its wild relatives (or, as they erroneously thought, the original wild potato), which could be crossed with the cultivated European varieties in an attempt to produce different and hardier varieties. The disastrous blight disease in Ireland of 1845 and 1846, caused by the fungus *Phytophthora infestans*, and the famine consequent on it gave an added impetus to these searches. Several wild species were brought to England a little later, such as Lindley's *Solanum demissum* and *S. cardiophyllum*, both of which are highly resistant to blight but were not used at that time in breeding resistant varieties. By an unlucky chance Lindley appears to have secured a variety or form of *S. demissum* susceptible to blight, whilst *S. cardiophyllum*, although blight resistant, was considered to be so distinct from the cultivated potato as to be incapable of breeding with it—an opinion fully justified by later experience. Certain other wild potatoes, such as *S. Commersonii* and *S. Maglia*, were brought to

Europe, but these were also of little use since they proved highly sterile and incapable of crossing with our domestic types. Sporadic attempts to introduce various wild potato species were made, nevertheless, all through the 19th century, but were attended by little or no practical success. As early as 1848 Lindley mentions an unsuccessful attempt made by the Royal Horticultural Society to acclimatise truly cultivated potatoes from Peru in this country. The reasons for their failure are quite clear now, but we shall have to refer to them in greater detail later.

At the beginning of the 20th century, Dr. R. N. Salaman showed that *S. demissum* was resistant to blight and that this resistance was an inherited character. He started breeding work with this species, and also another species known as *S. edinense*. This was undoubtedly the pioneer work in modern potato breeding and marked the beginning of a completely new era, namely the *scientific* improvement of the potato under man's control.

The final impetus, however, was given by the Russians who sent out several scientific expeditions to the Americas between 1927 and 1933 to collect native food plants, among them the potato. They set the fashion for large-scale surveys of this sort, driving home the point that plant breeders could not hope to obtain any adequate realisation of the material available by relying only on chance samples sent them by free-lance botanical collectors. Sweden, the U.S.A., Germany and Great Britain followed suit, the result of the British expedition sent out by the Imperial Agricultural Bureaux (one in which the present writer took part) being the formation of a collection to over 1,000 samples of native Mexican and South American potatoes. This collection and those made by the other countries mentioned above form an invaluable reserve of types for breeders all over the world, providing the greatest variation to choose from in their efforts to produce potatoes free from blight, frost, and damage by sundry other diseases and pests.

Distribution of the Wild Potatoes

Our botanical and genetical knowledge of the potato has been vastly increased by the data obtained on these expeditions. Whereas very few of the wild species had been known and studied in the living state, several score have now been thoroughly examined. Wild species of potatoes were found growing in nearly every country in South America, in addition to the southern states of the U.S.A., Mexico and several of the Central American republics.

They occurred in almost every region inhabitable by land plants—on mountain plateaux (some as much as 13,000 feet above sea-level), in sandy and salty deserts, sub-tropical forests, and on wide rolling plains. Some were so dissimilar in appearance to the ordinary potato plant that at first sight and without adequate botanical knowledge the observer would be inclined not to realise that they were at all closely related. Two species of this sort are shown in Figs. 7 and 8. Certain types were found to be resistant to 8° or even 10°C. of frost, others to blight, wart, Colorado beetle, virus, scab and many other potato diseases and pests. In all, some 200 wild potato species have now been described, though by no means all of these have been studied in the living state.

FIG. 8.—*Solanum simplicifolium*, a simple-leaved wild potato from northern Argentina.

A completely new fact that has emerged from the studies of the living species is the appearance of a polyploid series of species that differ in respect of their chromosome number. The chromosomes, the small rod-like bodies in the nucleus of the cell that bear the genes or hereditary determiners, are in general constant for any one species. Those of the cultivated potato had been counted in 1926-7 and found to be 48 in the ordinary potato cell, 24 in the sex cells. When studying the chromosomes of the indigenous American potatoes, however, the Russians discovered certain species with 24 body or "somatic" chromosomes, others with 36, 48 or 60 somatic chromosomes, and still others with 72. Here we see what is known as a polyploid series with the basic number of 12, the diploid species (with 24 chromosomes) being the most ancestral, from which those with higher numbers have derived by duplication of the chromosomes. The knowledge of chromosomes, therefore, gives us certain knowledge of the evolution and botanical relationships of the potato species.

Our knowledge of the cultivated potato has likewise been vastly increased as a result of the last 20 years' work. Before 1929 only one cultivated species was known, but at the present time some twenty have been described as a result of the work done by Russian and the British

MAP 1. *Distribution of Diploid and Pentaploid Cultivated Potatoes in South America*

———	*Solanum stenotomum*	(2*n* = 24)
— — —	*Solanum Yabari*	(2*n* = 24)
●●●	*Solanum Churuspi*	(2*n* = 24)
·····	*Solanum goniocalyx*	(2*n* = 24)
●●●	*Solanum Cardenasii*	(2*n* = 24)
○○○○○	*Solanum phureja*	(2*n* = 24)
— · — · —	*Solanum ajanhuiri*	(2*n* = 24)
●●●	*Solanum Ascasabii*	(2*n* = 24)
○—○—○	*Solanum Kesselbrenneri*	(2*n* = 24)
+++++	*Solanum Rybinii*	(2*n* = 24)
▪▪▪▪▪	*Solanum curtilobum*	(2*n* = 60)

expeditions. Maps 1 and 2 give an indication of the distribution of indigenous cultivated potatoes, showing that they are completely confined to the Andes of South America and to a small portion of southern Chile.

It will be noticed from the maps that the most widespread species is the tetraploid (48 chromosomes) species, *Solanum andigenum*, occurring in Venezuela, Colombia, Ecuador, Peru, Bolivia and North Argentina. It was from this species, in the opinion of the writer, that our European potato was derived.

Diploid cultivated potato species (with 24 chromosomes) are to be found in Colombia and Ecuador, but chiefly in South Peru and North Bolivia, as is also the case with the triploid species. The one cultivated pentaploid species (60 chromosomes), *S. curtilobum*, is also found in this region. We mentioned in an earlier part of this article that the Cuzco—Lake Titicaca region of southern Peru and northern Bolivia was in all probability the centre of origin of the cultivated potato. We can see now that not only is the number of varieties cultivated in this region greatest, but the largest number of species is to be found here also.

One cultivated tetraploid species (48 chromosomes), noted on the map as *S. tuberosum*, is seen to be quite isolated from the others, occurring in the coastal regions of southern Chile and on the island of Chiloé. This would seem to be very closely related to *S. andigenum*, and was considered by Dr. S. M. Bukasov to be the source of our European potato.

The cultivated potatoes in South America, besides being much more varied in shape, size and colour than the European type, vary much more also in their physiological attributes. Thus, three species—*S. Juzepczukii*, *S. ajanhuiri* and *S. curtilobum*—are frost-resistant. Others, such as *S. phureja* and certain varieties of *S. andigenum*, possess a relatively high protein content; others again—*S. Rybinii*, *S. Kesselbrenneri*, *S. Cardenasii*, *S. Ascasabii*, *S. phureja*—are early maturing, with no dormancy period, and can be grown all the year round in regions where lack of frost and adequate moisture supply render this possible.

Most of the Andean potatoes grow best at an altitude of about 10,000 to 12,500 feet where the climate is temperate, though the frost resisters are to be found at higher altitudes—up to 13,500 feet—and these, because of thier bitter taste when fresh, are used almost exclusively for the making of chuño and tunta. The species with short dormancy are capable of withstanding a much hotter, almost sub-tropical, climate, and it is hoped that they may later prove to be of some value in the breeding of potatoes for the tropical regions of the world.

A survey of the native American potatoes would not be complete without some mention of their reaction to length of day. Most grow in tropical latitudes where the length of day in the growing season is roughly 12 hours; they possess, it has been found, a photoperiodic response to day-length, only maturing good crops of tubers under a day-length of more or less 12 hours, and when subjected to a greater day-length failing to yield or producing a very small amount. This is the reason why so many native potatoes when introduced into this country fail to form tubers, though if given an artificial short day they yield quite well. The best cultivated potato species in Peru, *S. goniocalyx*, the "papa amarilla" or Golden Potato,

with a very fine flavour and golden yellow flesh, has several times been brought over here, as we mentioned earlier in this article; it has failed to do well, however, on account of its adverse reaction to long summer days; *S. andigenum*, however, does give a yield, though generally rather poor and later in the season, and thus could have been introduced into Europe without it dying out, as *S. goniocalyx* has always done.

Selection to suit English Climate

We have already mentioned that the potato was not universally acclaimed for quite a considerable time, several centuries in fact, after its first arrival in Europe. In the opinion of the author this was due to the poor yield consequent on the short day reaction of this species. Later, it gradually improved, since it was often grown from seed, and naturally the best-yielding seedlings would have been retained and the poorer ones discarded. Selecting for yield would be the same, in this case, as selecting for less marked short-day types, until finally the potato became quite well adapted to the long days of our English summer and could hold its own with the other crops. This level of productivity probably was reached about the middle of the 18th century, though the early varieties which mature in late July and early August have only been produced comparatively recently. These, it is obvious, are even more extreme long-day types than the maincrop varieties, which do not mature until September or October.

Earlier in this article I dealt with the introduction of the potato into Europe but did not examine in any great detail the evidence for its point of origin in South America, except to say that it probably came from Colombia. Having examined some of the modern work, however, we are in a position to deal more fully with this point[1]. The Russian geneticists, headed by Drs. Vavilov, Bukasov and Juzepczuk, considered that the European potato came not from the Andes but from Chile, and have consequently given the Chilean potato the name *S. tuberosum*, the European sorts, to which they accord the name *S. tuberosum*, var. *europaeum*, being considered by them a variety of this species. They base their evidence chiefly on the fact that the Chilean potatoes are already adapted to a long day and would consequently yield well when brought to Europe. However, several facts militate against the acceptance of this view. In the first place, Chile had not been conquered by the year 1570, when the potato first became known in Europe. Secondly, conditions of travel at that time were such that it would have been impossible to preserve a potato for the length of time needed to transport it from Chile to Spain.[2] We have just noted, furthermore, that the potato when brought to Europe was not a good yielder, so that it is not necessary to postulate the necessity of a long-day adapted plant when first introduced. Finally, we have seen from the story of the

[1] A detailed account of the evidence for this and the other arguments advanced in the present article will be found in the author's *Potato Collecting Expeditions in Mexico and South America. II Systematic Classification of the Collections.*

[2] The evidence has been very thoroughly set out by Dr. R. N. Salaman in the last instalment of his paper which was referred to earlier.

MAP 2. *Distribution of Triploid and Tetraploid Cultivated Potatoes in South America*

++++++	*Solanum Juzepczukii*	(2n = 36)
o-o-o-o	*Solanum chaucha*	(2n = 36)
.....	*Solanum tenuifilamentum*	(2n = 36)
●	*Solanum mamilliferum*	(2n = 36)
◍	*Solanum coeruleiflorum*	(2n = 36)
-·-·-	3x hybrids	(2n = 36)
———	*Solanum andigenum*	(2n = 48)
◒	*Solanum tuberosum* [according to Dr. S. M. Bukasov]	(2n = 48)

English potato described by Gerard that its most likely source was from Santa Fé de Bogotá via Cartagena and thence by Drake's ships to England. No doubt the Spanish potatoes also came either from Colombia or from Peruvian or Bolivian potatoes grown for a season or two in Panama.

To conclude this account of the history of the potato we shall try to sum up briefly the main points mentioned above:

The potato was first brought into cultivation by the Indians of Cuzco and Lake Titicaca, at least as early as the second century A.D. and probably much earlier. From its centre or origin it spread both northwards and southwards along the Andes in a number of different species of differing chromosome numbers and physiological attributes, some forms reaching as far south as South Chile. The first written record by Europeans dates back to 1537, when it was seen in Colombia, later chroniclers noting its presence in other parts of the Andes also.

It was probably brought to Spain as ships' stores about 1570 and from there spread to Italy, Belgium, Germany and other countries. Another introduction, this time into England, took place between 1581 and 1596. The plant introduced was *Solanum andigenum*, the 48-chromosome species from the Andes. This yielded poorly at first, though possibly it did better in Spain and Italy, until it had been improved by growing from seed and selecting for yield, thus eliminating its adverse reaction to long days.

The potato did not become universally popular, except in Ireland, until the middle of the 18th century, when it was grown extensively all over Europe. From Europe it spread to all the parts of the world that the Europeans colonised, becoming of ever increasing importance even in those countries with climates very far removed from those of the temperate regions to which the potato was once thought to be restricted.

(The maps on pp. 44 and 45 are reproduced by courtesy of the Clarendon Press.)

LETTERS TO THE EDITOR

Laboratory Technicians

SIR,—I am glad to see that DISCOVERY has taken up the future of laboratory technicians, but the problem is a very difficult one.

Without doubt there will be room for many more workers, both men and women, in laboratories after the war, especially in the smaller teaching institutions. At present authorities are often quite unaware of the value of such workers to the efficiency of a laboratory and usually think that some unskilled "bottle-washer" is all that is needed. But, as every scientific worker knows, a trained technician is far more than that.

The first task is to persuade the appropriate authorities that the laboratory technician is essential for the proper working of a laboratory, and also that he should be given adequate status and pay, so that there is an inducement to men and women to make it their career. It would also be a good thing if the social gulf between the scientific worker and the technician could be narrowed somewhat, so that the technician does not feel that he is a mere servant.

But the greatest difficulty is that of training. At present there is no way by which anyone who wants to become a laboratory technician can readily set about it. Technical colleges might help, but the ordinary courses in science that they run are not as a rule suitable, being in the main too academic. A short basic course of science is obviously required, but the technical side and the knowledge of the running of a laboratory cannot best be imparted by the ordinary science lecturer. This might be done by using skilled technicians as lecturers, though it will probably be hard to find any who would be willing after a long day in their own departments to devote certain evenings to such work.

Most of the skilled men have grown up in laboratories and have begun as "lab. boys" and it might be best if some system of apprenticeship be devised. Here big departments in the universities and some of the large firms of scientific instrument manufacturers could play an important part. But the whole lacks planning, which is not made easier since the training needed for a chemical laboratory will differ markedly from that, say, for a biological. Furthermore, the numbers needed for the various sciences are very different so that some control of entry is essential. Also, two plans are really necessary, a short-term one for people coming from the forces and a permanent one for youngsters leaving school.

Is not this a problem that needs the joint consideration of representative scientific bodies with the Ministry of Labour? —Yours etc., C. C. HENTSCHEL.

Scientific Literature for Europe

SIR,—The appeal for scientific literature for France (DISCOVERY, Jan., 1945, p. 30), reminds me of a matter which, in my opinion, needs the immediate attention of our Government. In December you published a report of a speech in which I emphasised how important it was that British "Master Key" Industries should replace Germany as the leading supplier of scientific equipment in Europe. My work on behalf of these industries has made it clear to me if we are to be successful we must give serious attention to the supply of scientific literature, information and service of every kind. Several people who are very familiar with continental practice have come to me and pointed out that German infiltration by means of books of reference, scientific journals, text books, trade catalogues and similar means has been so complete and has continued for such a long time that we shall suffer under a most serious handicap unless we can make a tremendous effort to supply the British equivalent and give all the scientific assistance which our Allies formerly obtained from Germany. Many refugee scientists are surprised to find that we are as advanced as Germany in our scientific knowledge and equipment, and have indeed taken the lead in many directions.

It is a gigantic task to cover every branch of science and engineering and produce for each a complete set of literature in various continental languages. We have to cater for the student, the industrial worker and research workers and at every point we must tell the reader what British science is doing and what British equipment is available. We have, perhaps, five years in which to achieve an object which took our enemies 70 years of patient and intensive work. It is impossible for individual firms, or even groups of firms to attempt to tackle this problem on an adequate scale and if they did there would be lack of co-ordination and much waste of effort and overlapping. To me it appears to be essential that some organisation should be set up under Government auspices and supplied with public funds. They should prepare a complete outline of the task and spare no effort or expense to set the right people to work to fill in the details and provide the complete picture. The whole of Europe should be flooded with carefully prepared literature of every kind in the language of each country and this should be accompanied by co-operative schemes of supply and of service.

Such a plan might cost this country £20,000,000 spread over a period of years but in time it would become self-supporting and would eventually be the most profitable investment we ever made. It would contribute to our security and give our continental friends confidence in us and encourage them to believe that we really do mean to play our part in European family life.—Yours etc., NORMAN SHELDON, A.R.C.S., F.R.I.C.

In the previous issue Professor Robertson traced the development of science in Canada from the 17th century up to the formation of the Royal Society of Canada and then dealt with the pioneer work done in astronomy, geology, mineralogy, botany and zoology. The second half of the article covers physics, chemistry and medical science, and concludes with a reference to the work of the National Research Council.

A Survey of Science in Canada*

J. K. ROBERTSON, F.R.S.C.

PRESIDENT OF THE ROYAL SOCIETY OF CANADA

It should be evident that the natural resources of Canada have been responsible for much of her scientific development. In the future this will be true as much as in the past, because natural resources can suffer depletion. Wasting assets like minerals and coal do not last forever, and the wealth of forest, land and ocean is only self-producing and inexhaustible if it is properly conserved. In agriculture, in spite of excellent colleges which date back to 1859 in Quebec and 1874 in Ontario, and of faculties of agriculture in the western universities, there are serious maladjustments owing to unscientific methods of farming. Land has been misused and soil fertility depleted; in some districts the acreage of unimproved land has increased, and in others erosion due to wind and water has impoverished top soil.

In Canada wild-life resources are the mainstay of the human population in 52% of the entire land area. And yet, to quote from a recent report issued by the Federal Department of Mines and Resources: "The available supply of physiological, ecological and economic data relating to our wild life resources is still extremely meagre . . ." In forestry, pioneer waste when resources seemed limitless, fire destruction, and inadequate scientific management have altered the "metabolism" of certain parts of the country and created a need for re-afforestation, conservation and improved control—all this in spite of much praiseworthy work done in the past by the Canadian Forestry Association and other agencies.

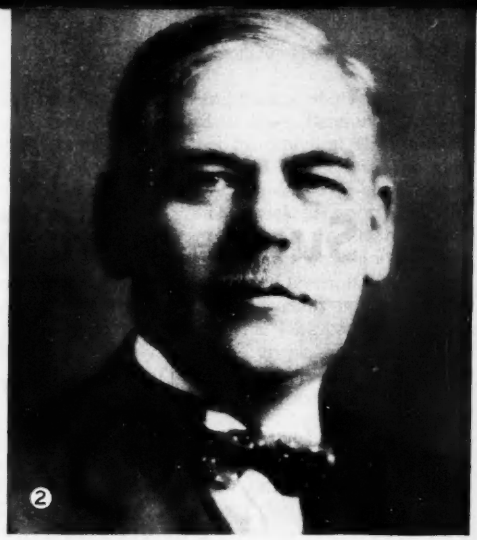
These are but a few of many examples which could be given to emphasize the need for improved scientific management of our resources in the future. Fortunately Canadian scientists have not been inactive, and in the present period of planned reconstruction they are taking an active part. Among other things, they are urging the extension of soil surveys similar to one recently completed in the Ganaraska watershed in Central Ontario; the establishment of permanent centres where long-term scientific research observations can be made about the ecology of plants and animals and other factors relating to natural resources; and the examination scientifically of the possibility of linking agriculture more closely with modern chemurgy and of utilizing farm products more widely and more wisely. It is a satisfaction to record that progress is already being made along these lines and that governments are showing every indication of co-operating with scientists. To give a single example: in its 1944 Budget the Government of Ontario made a large appropriation to be used for scientific researches relating to the natural resources of the province.

In geology and mineralogy, in spite of the fine record of the country in this field, the future is full of problems. Over two and a half million square miles of Canadian territory is imperfectly known geologically and only 10% of the total area has been surveyed to a scale of four miles or less to the inch. The possibility of distilling coal underground and the possible establishment of synthetic industries near coal mines have yet to be explored. Numerous problems arising from the depletion of mines have to be solved and increased attention paid to the use of light metals. In this field it is gratifying to note the development by Pidgeon, working at the National Research Council, of a satisfactory method for extracting magnesium from dolomite, and the important work of Goudge of the Bureau of Mines on the production of brucite from magnesium.

Astronomy and Meteorology

Although valuable practical astronomical work had been done by the Department of the Interior in connection with surveys of western lands and the marking of boundaries, and although the position of Chief Astronomer, first held by W. F. King, was created in 1890, it was early in the twentieth century before the real beginning of scienific work in this field was made. In 1903 the building of a Dominion Observatory at Ottawa was started and in a few years active work was under way, with King as Director. From the outset investigations in this observatory have centred around the following main divisions: (*a*) geophysics, including seismology by men like Klotz and Hodgson, terrestrial magnetism, initially supervised by French, and gravity determinations by Miller; (*b*) meridian work, under the supervision of the present Director, R. M. Stewart; and (*c*) astrophysics, with special reference to stellar and solar spectroscopy initiated by Plaskett and De Lury. The work in the latter field with a small refractor was so successful that in 1913 the Dominion Government authorised the erection of an observatory with a reflecting telescope of large aperture. The site at Victoria, B.C., was carefully chosen and in 1918 the Dominion Astrophysical Observatory made its first observations with a 73-in. reflector. The work at this observatory on the measurement of radial velocities and stellar orbits, on spectroscopic binaries, on the rotation of

* Concluded from p. 13 of the January Number.



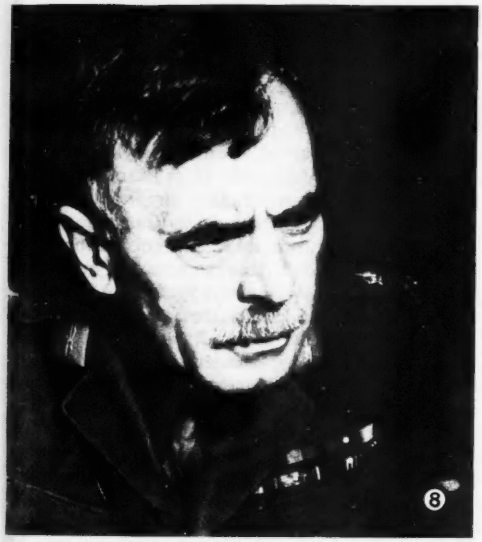
1.—Sir John McLennan, head of the physics department at the University of Toronto from 1906 to 1932.

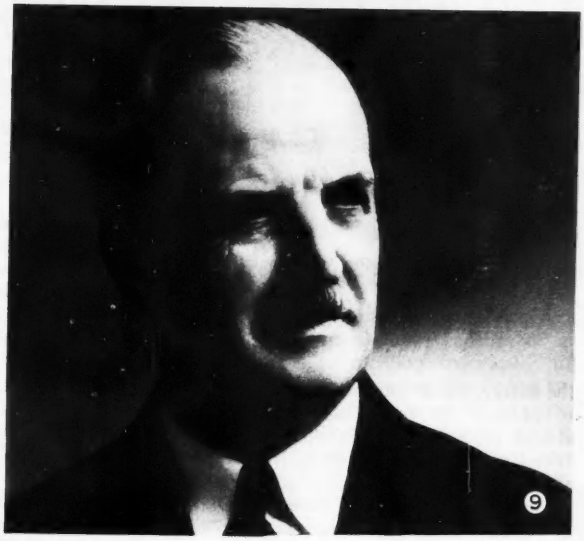
2.—Professor E. F. Burton, head of the physics department and director of the McLennan Laboratory, Toronto University, since 1932.

3.—Sir Frederick G. Banting (1891—1941).

4.—Surgeon Captain C. H. Best, director of the Banting-Best Department of Medical Research, Toronto.

5.—Dr. J. B. Collip, director of the Research Institute of Endocrinology, Montreal.





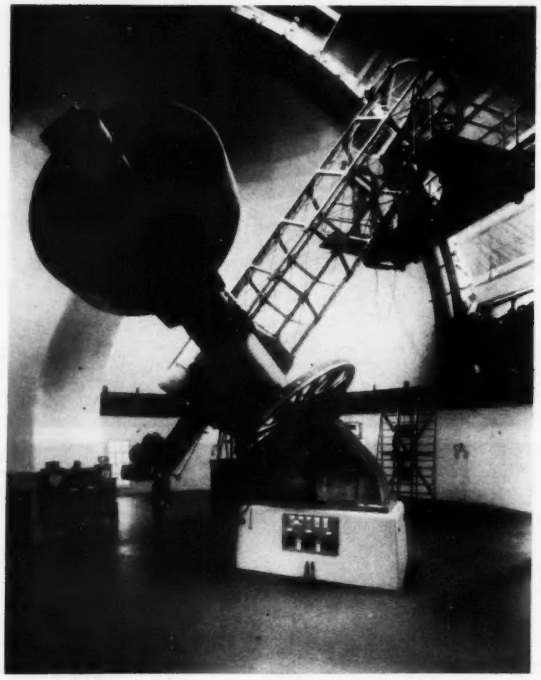
6.—Dr. John Stanley Plaskett (1865—1941). Founder of the Dominion Astrophysical Observatory, Victoria, British Columbia, which he directed from 1917 to 1934.

7.—Dr. H. M. Tory, for many years president of the National Research Council of Canada.

8.—Major-General A. G. L. McNaughton, who presided over the National Research Council until he came to Britain early in the war as Commander of the 1st Division, Canadian Overseas Force.

9.—Dean C. J. Mackenzie, who took over the direction of the National Research Council in Major-General McNaughton's absence.

10.—Dr. Frère Marie-Victorin, director of the Botanical Gardens, University of Montreal.



Dome of the Dominion Astrophysical Observatory, Victoria, B.C., with 73-inch Reflecting Telescope.

the galaxy, on interstellar matter and the universal nature of physical constants has been outstanding and will always be associated with the names of its first three Directors—J. S. Plaskett, W. E. Harper, and J. A. Pearce—and astronomers like Young, Beals, Petrie and McKellar. Young is now Director of the David Dunlap Observatory at Richmond Hill, Ontario, where a 74-in. reflector has been in operation since 1935. This observatory was erected largely through the efforts of C. A. Chant, who as Professor of Astronomy at the University of Toronto has trained the vast majority of Canadian astronomers in Canada.

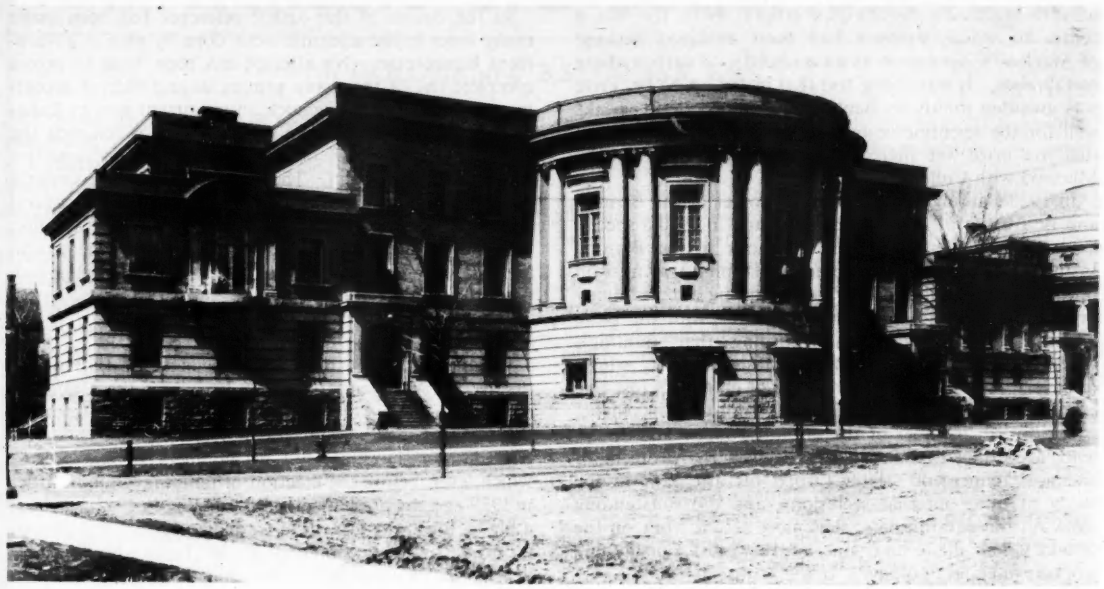
In meteorology the pioneer work of the first Director of the Service, Sir F. Stupart, has been followed by a period of ever-increasing expansion under the direction of the present Controller, Dr. J. Patterson. With Canada's Arctic and sub-Arctic regions and vast extent of territory and with its strategic position in connection with international aviation, the need for a first-class service has been recognised, and in recent years a marked expansion has taken place. By means of pilot balloons observations of temperatures and other data taken for many years have added greatly to our knowledge of upper altitudes, and more recently, regular airplane ascents have been used "to determine the physical properties of the air in the vast air currents over North America." Observational work has gone hand in hand with excellent theoretical studies in the dynamics and thermodynamics of the atmosphere.

Physics and Chemistry

In 1893 Sir William Macdonald, among other benefactions to McGill University, endowed a Research Chair of Physics. In many ways this marked the beginning of the modern era in physics, because it was followed in the next decade or two by a marked expansion in research. H. L. Callendar, the first holder of the McGill chair, carried out important investigations in heat and in electrical measurements, and greatly stimulated men like H. T. Barnes, with whom he made a determination of the value of the mechanical equivalent of heat which is now a classic. Barnes, who was the third occupant of the McGill research chair, became widely known through his work on microthermometry and ice-engineering, dealing with problems of vital importance in Canada. The second holder of the research chair was Rutherford, who between 1898 and 1907 made McGill a famous centre with his early investigations in radio-activity. It was during this period that he and Soddy worked out the theory of radio-active disintegration, and it was while Rutherford was at McGill that many valuable researches were carried out by men like Eve, Barnes, Bronson, Boyle, McClung and others, as well as by scientists from Europe.

At the turn of the century another important development in physics was taking place. Canadians were crossing the Atlantic to work at the Cavendish Laboratory under Sir J. J. Thomson. Among these the most outstanding in the nineties was probably J. C. McLennan, who worked at Cambridge in these early days with Rutherford, the present Lord Rayleigh, Townsend, C. T. R. Wilson, and others, who later became prominent physicists. McLennan's subsequent work at Toronto was a remarkable achievement. With almost superhuman energy he directed the affairs of his department and built up a research school from which a steady output of papers on atomic physics, spectroscopy and low temperature phenomena continued until his retirement. It is interesting to note that the pioneer work on penetrating radiation, the forerunner of cosmic rays, was done as early as 1901-03 by McLennan and Burton (his successor at Toronto) and independently by Rutherford and Cooke. Of McLennan's many researches, special mention should be made of his investigation of ortho- and para-hydrogen and his work with Schrum on the origin of the auroral green line.

Many of McLennan's students followed his example by going to Cambridge, and many more physicists studied in England after Rutherford went to Manchester in 1907. In more recent years the Cavendish has had a third generation of young Canadians, most of them holders of 1851 Exhibition Research Scholarships. Consequently the British tradition in physics is strong in most Canadian universities, although this in no way belittles the excellent work done by men trained either in Canada or in the United States. It is significant, however, that Burton, Director of the McLennan Laboratory at Toronto, Shaw, Director of Physics and Keys Macdonald professor at McGill, Dawes, Director at McMaster, and the writer of this article, at Queen's, are all Cavendish men.



The McLennan Laboratory of the University of Toronto.

The founding of research professorships at other institutions has been another important factor in Canadian physics. As holders of such chairs, Hughes and Gray at Queen's, and Henderson, Alty and Herzberg at Saskatchewan, have all made valuable contributions. In this group also should be placed the name of L. V. King, a Canadian who did outstanding work in theoretical physics and in the solution of such practical problems as the penetration of fog by sound.

In applied physics work of importance has been done in geophysics by men like Gilchrist and Keys, in atmospheric physics by Currie, and in soil physics at the University of Alberta. In industry, however, Canadian physicists are not utilised to anything like the same extent as chemists, nor are they yet organised into a national group to form an Institute of Physics. Such organisation cannot long be delayed and will probably be one of the consequences of the way in which the war has emphasised the basic importance of physics.

The position of chemistry in this respect forms a striking contrast with physics. The existence of three major Canadian chemical societies and an active journal, *Canadian Chemistry and Process Industries*, gives some indication of the position which chemistry occupies in Canada. This year, it should be noted, the chemists took a forward step by amalgamating these three groups into the Chemical Institute of Canada. In this organisation there is a happy blend of university and industrial representatives. Thousands of illustrations could be given of the importance of the chemist in Canadian industry, but two must suffice. The tremendous plant at Shawinigan Falls, Quebec, is an outstanding example. Here the process for making acetaldehyde from acetylene was developed, here acetic anhydride is made from acetate, and vinyl chloride and polyvinyl alcohol for plastic products The second example is the plant at Port Hope, Ontario where radio-active ore, brought some 4,400 miles from Great Bear Lake, is purified.

In fundamental research the Canadian chemist has made so many contributions in the various branches of his subject that one hesitates to mention specifically any names, but it is perhaps not invidious to give one or two examples. There comes to mind the work of Maass in physical chemistry, and of Steacie on the mechanism of chemical reactions; the discovery by Manske and Marion of a large number of new alkaloids by careful examination of various species of plants; and the contributions of Hibbert and his co-workers in carbohydrate chemistry and on the structure of lignin.

Although war research is not included in this article, the work of Canadian chemists and botanists on the possibility of obtaining rubber from Canadian plants is such an excellent illustration of co-operative work that it is recorded here as one of many indications of what may be expected in the future.

Medical Science

Of the many ramifications of chemistry none is more important than its position in regard to the medical sciences, and it is not surprising that the most outstanding Canadian contribution in medicine is in the field of physiological chemistry. Reference is made to the discovery by the Toronto group, Banting, Best, Collip and Macleod of the method of extracting from the pancreas the hormone insulin. It was no accident that Banting, who had conceived the idea of "attacking the problem of extracting the islet cells by ligating the pancreatic duct"

went to Macleod's physiological laboratory in Toronto, a centre to which students had been attracted because of Macleod's reputation as an authority on carbohydrate metabolism. It was fitting too that in 1923 a Nobel Prize was awarded jointly to Banting and Macleod. It speaks well for the scientific co-operation of this famous group that this prize was shared by Banting with Best, and by Macleod with Collip.

In 1923 Banting became the first holder of the Banting and Best Chair of Medical Research and in 1930 a special laboratory was provided for this work in the Banting Institute. Here, until an airplane crash on a war mission brought a sad ending to his career, Banting directed many investigations combining clinical research with the basic sciences. It scarcely needs recording that Banting's successor as Director of the Institute is Best, whose discovery of the dietary importance of choline is just one example of the many important contributions he has made.

The fourth member of the insulin group, J. B. Collip, who, according to Banting, was "given the problem of chemical refinement", later turned his attention to the study of other internal secretions, and did outstanding work on the parathyroids. His more recent work on the pituitary has made him one of the most outstanding workers in endocrinology.

In physiological chemistry mention should also be made of earlier work done by A. B. Macallum at Toronto and by Ruttan at McGill, as well as the investigations of F. R. Miller on the nervous system which were of sufficient importance to bring him an F.R.S.

In pathology sound contributions have been made in Canada, beginning with the work of Sir William Osler, another charter member of the Royal Society. Coming down through the years we encounter such names as Johnson, Adami, Oertel, and Maude Abbott at McGill, Masson at the University of Montreal, MacKenzie, Brodie and Klotz at Toronto, and Connell and Miller at Queen's. Until comparatively recently bacteriology was associated with pathology, but in most Canadian universities this subject now has its own department. The work of Connell on the bacteriology of milk and cheese, of Reed on types of tubercle bacilli and on gas gangrene, of Holman on streptococci, and of Murray on meningococci are examples of some of the achievements in this field.

In preventive medicine and hygiene Canada has been active through the combined work of excellent governmental departments of health and the universities. Particular mention should be made of the School of Hygiene at Toronto founded in 1924 to serve as a national centre for post-graduate teaching and the associated Connaught Laboratories, whose first Director, J. G. Fitzgerald, along with D. T. Fraser became "widely known for their work on scarlet fever toxin and the use of toxoid in the prophylaxis of diphtheria."

Even a very brief reference to Canadian medical science would be incomplete without a reference to J. P. McMurrich, an anatomist whose career was so varied that he made contributions of value in vertebrate morphology, embryology and anatomy and at various times and various places was Professor of Biology and Horticulture, Instructor in Osteology and Mammalian Anatomy, Professor of Biology, Professor of Natural History, Professor of Anatomy and Chairman of the Biological Board of Canada.

In the course of this article reference has been made many times to the scientific work done by men in government laboratories. No attempt has been made to give a complete list of the many provincial and federal departments which are playing such an important part in Canadian science but, with two exceptions, it is felt that the examples which have been cited give a representative picture of the situation. The first exception is the Ontario Research Foundation, which under government control and the guidance of Speakman is helping in the solution of many problems connected with industry. The second and more important exception is the National Research Council.

Origin of National Research Council

Organised in 1916 because of needs at the time of the first World War and originally known as the Honorary Advisory Council of Scientific and Industrial Research, this is the most important purely scientific body in Canada. In the successful development of the N.R.C. which, even before the erection of temporary laboratories in 1929 and the present splendid building in 1932, has been a big factor in the growth of Canadian science, credit must go primarily to the genius of H. M. Tory, who for many years was its President. The rapid expansion since his retirement under the guidance of his successor, General McNaughton, and then under Dean C. J. Mackenzie, is a tribute to the wisdom of the broad policy which Tory developed and whose fruits he saw long before his retirement.

This policy was a four-fold one: (*a*) Money was made available for assisting research workers anywhere in Canada with approved programmes and also for the awarding of studentships and bursaries (*b*) associate committees of representative scientists were set up to consider needs in various fields and to direct along broad lines research programmes: according to Dean Mackenzie, "at the present time there are approximately 40 main committees and 102 sub-committees actually engaged in directing research projects". In the present war, it may be added, some of these have done work of vital importance (*c*) in its own laboratories work somewhat along the lines of that done at the N.P.L., Teddington, is carried out in three main divisions. Physics and Electrical Engineering is directed by R. W. Boyle, chemistry by E. W. R. Steacie, and applied biology by W. H. Cook. Although there is no division for the medical sciences, the Council is active in this field also. (*d*) Since 1929 the Council has sought to develop a purely Canadian outlet for scientific papers in the *Canadian Journal of Research*. Because of the better known and more widely circulated journals of England and of the United States the task has not been easy, but progress is being made. At present under a joint editorial board representing the Council and the Royal Society the journal is published in six sections, and its importance is steadily growing.

In concluding this very general survey, the writer would like to emphasise that for obvious reasons no attempt has been made to discuss war research and that in a single article it has been impossible to do more than to mention a number of representative men and their accomplishments. He hopes he will be forgiven for his sins of omission and commission.

How Reliable are Social Surveys?

J. GOLDMANN, B.Sc. (Econ.), F.S.S.

DURING the war the scope of social surveys has widened considerably. Family budgets, radio listening, expenditure on clothing coupons, changes in body weight, the impact of the official "Dig for Victory" campaign, are but a few examples of the subjects investigated. Most of these inquiries are continuing investigations, using the technique of sample surveys and repeated periodically. Faced with a veritable flood of such surveys, the public is well entitled to ask, "What is the good of it all? Can the results be relied upon?"

Nobody would pretend that the results are invariably correct. Like every other method of research, surveys sometimes go wrong. Various devices, however, can be relied upon to give a fair warning of danger. It is our purpose to discuss some of the dangers and also some of the procedures that have been evolved to check the results.

Size of the Sample.

The larger the sample, the greater the popular confidence which will be placed in the results. Practical experience has shown, however, that a small-sized survey is more likely to supply a reliable picture than a large one. The history of budget inquiries is illuminating from this point of view. The American "Consumer Purchases Study" of 1935-36 (conducted by the Bureau of Labor Statistics and the Bureau of Home Economics) based its estimates of consumer expenditure on information from 60,000 families. A year or two later, British experts advised the Ministry of Labour, when that department was planning the 1937-38 inquiry on "Weekly Expenditure in Working-Class Households," that it should aim at collecting budgets from 10,000 households. In 1941-42 the United States Bureau of Labor Statistics based its estimates of the "Income and Spending and Saving of Urban Families in War-time" on information from less than 1,300 families. This is the smallest official survey yet undertaken for estimating income and expenditure on a national basis. It was claimed, and claimed rightly, that the survey yielded estimates of at least the same accuracy as those derived from the earlier and much larger Consumer Purchases Study. In this country there are many statisticians who maintain that the Ministry of Labour would perhaps have rendered better service if, instead of the two family-budget enquiries in 1904 and in 1937, it had carried out smaller surveys at more frequent intervals.

It is true that chance fluctuations of sampling are reduced as the size of the sample increases, although not in the same proportion. A percentage obtained from a sample of 2,500 is, for practical purposes, reliable within 3 per centage points; the chance is less than 1 in 300 that a larger error will occur because of a sampling fluke. A sample of 10,000 will be similarly reliable within 1·5 percentage points. In mathematical language, the margin of error of the estimate of a percentage from a sample is inversely proportional to the square root of the number in the sample. By increasing the sample to four times its previous size, as we did above, we have reduced the expected margin of error by only one half. It is possible to calculate the size of the sample necessary for any degree of precision.

In practical work, however, it will be found that chance fluctuations are usually of minor importance as compared with other disturbances, such as faulty selection of the sample, carelessness in the completion of forms, or bias on the part of the investigator. In a small investigation, local investigators can often be more carefully selected, supervision of their work offers less difficulty, and return calls can be made on those who refused to give information in the first instance. These advantages will often tip the balance in favour of the small sample, quite apart from the considerations of cost and speed. Only in exceptional circumstances, where it is desired to group the results under a fair number of subheadings, is a survey, in this country, based on a sample of more than 2,500.

For those who still do not feel at ease when asked to accept a sampling result, the following experience may be of interest. When the British Institute of Public Opinion had to analyse 24,538 questionnaires, from doctors giving their views on the National Health Service, tabulation of every fifth questionnaire was first made. This sample was intended to form the basis for a provisional report, which had to be submitted at a date when it would have been impossible to have had all the forms analysed. Since the completed questionnaires had been numbered consecutively in the order of arrival, it was easy to obtain a random selection by picking out every 5th form, totalling nearly 5,000. One hundred and twenty-eight percentages were obtained first from the sample and later these were recalculated from the complete tabulation. The differences between the sample figures and the final results are given in the table below:

TABLE I

A SAMPLING EXPERIMENT WITH QUESTIONNAIRES ISSUED TO DOCTORS.

Range of difference between sample figure and final result (*Percentage points*)	*Frequency of occurrence of difference*	*Frequency, as percentage*
From		
−1·5 to −2·0	1	0·8
−1·0 to −1·5	1	0·8
−0·5 to −1·0	10	7·8
0·0 to −0·5	55	42·9
0·0 to +0·5	44	34·4
+0·5 to +1·0	13	10·1
+1·0 to +1·5	2	1·6
+1·5 to +2·0	2	1·6
	128	100·0

It will be seen that none of the sample results differs from the final figure by more than 2 percentage points; the bulk of the sample figures are correct within 1 percentage point. When the data were further analysed it was

1a Have you ever been an in-patient of a hospital? — **Yes—Private Ward** ..... 11; **Yes—Other** ..... 12; **No** 13

b If YES: Was it a municipal or voluntary hospital? — **Municipal** ..... 14; **Voluntary** 15

c Were you satisfied or dissatisfied with the way you were treated? — **Satisfied** ..... 16; **Dissatisfied** ..... 17; **D.K.** 18

Comment .....

2a Have you ever attended the Out-Patient Department of a hospital

1. As a Casualty? — **Yes** ..... 19; **No** 20
2. Other — **Yes** ..... 21; **No** 22

b If YES: Were you satisfied or dissatisfied with the way you were treated? — **Satisfied** ..... 23; **Dissatisfied** ..... 24; **D.K.** 25

c Why? .....

d Was it a voluntary or a municipal hospital? — **Voluntary** ..... 26; **Municipal** 27

3 Should voluntary hospitals remain voluntary, should they be run by a public authority, or should they become partly voluntary and partly public? — **Voluntary** ..... 28; **Public** ..... 29; **Mixed** ..... 30; **D.K.** 31

Comment .....

4 Have you your own doctor, to whom you go if you are ill? — **Yes** ..... 32; **No** 33

5a When did you last see a doctor? ..... week(s) ago

b Where? — **Panel** ..... 34; **Works** ..... 35; **Hospital** ..... 36; **Private** ..... 37; **Dispensary** ..... 38; **Clinic** ..... 39; **Municipal** 40

6a Can you get doctor's treatment free — **Yes** ..... 41; **No** 42

b If NO: Have there been times when you did not go to see a doctor but would have gone if there had been no charge? — **Yes** ..... 43; **No** 44

7 If you were entitled to attend your doctor free of charge under a public health service, would you do so, or would you attend him privately and pay fees? — **Attend** ..... 45; **Pte** 46

Why? .....

8a Are you taking any medicine regularly? — **Yes** ..... 47; **No** 48

b Was it ordered by a doctor? — **Yes** ..... 49; **No** 50

c If YES: What is it? .....

9 On the whole, would you like the idea of a publicly run National Health Service, or would you prefer Hospitals and doctors to be left as they are? — **N.H.S.** ..... 51; **As they are** ..... 52; **D.K.** 53

Comment .....

10 Who do you think should have most to say about the way medical services are arranged, the doctors, or the public through the Government? — **Doctors** ..... 54; **Equal** ..... 55; **Public** ..... 56; **D.K.** 57

Comment .....

11 Would you approve or disapprove of health centres, where you might get more treatment than you could get at your doctor's surgery, but which might not be so near your home? — **Approve** ..... 58; **Disapprove** ..... 59; **D.K.** 60

12a If we do not have a National Health Service, do you think that it is best to get rid of the Panel, leaving only private doctors, or should we try to make some system as the Panel work satisfactorily? — **Abolish Panel** ..... 61; **"Panel" System** ..... 62; **D.K.** 63

b If "Panel" System: How could this best be done? .....

.....

Man 1
Woman 2

21—29 3
30—49 4
50 and over 5

N.H.I. 1
Not N.H.I. 2

Hosp. Svg. Sch. 1
Not Hosp. Svg. Scheme 2

Married 1
Single 2

Av + ... 6
Av 7
Av — 8

Group D 1
(Mark Av— also)

Days sickness in **June** .....
(in figures)

Child 14 or under ... 1
No young child 2

Professional, Salaried-Executive 1
Salaried-Clerical 2
Propr., shop or business, farmers 3

Weekly wages:
Factory, heavy industry, transport 4
Miner 5
Agricultural workers (Ex. farmers) 6
Weekly wages, all others 7
Housewives 8
Retired, unoccupied 9

Occupation (write in) .....

Put ring round appropriate Nos. for answers and keys.
USE SOFT PENCIL.

Reporter's No.: ...../.....

Date .....

Does the public want a National Health Service? This is the questionnaire used to find the answer. The information to be entered on the bottom of the form will help to check up on the representativeness of the sample. Note on the questionnaire the "pre-coded" replies, the value of which is referred to in the text.

found that the differences that occurred were in good agreement with the margins expected from theory.[1]

Even more striking than the above were the results of a preliminary tabulation. In the early days, when the first questionnaires were coming in, the British Institute of Public Opinion wanted to know how the results were shaping. One thousand forms were analysed. On no answer did the results from this 1,000 differ by more than 4 percentage points from those of the final, complete tabulation. There are good grounds for believing that, even within this narrow margin, the largest differences were due not to sampling fluctuations but to the fact that Service doctors naturally tended to reply later and their views tended to differ from those who had replied earlier.

Ensuring Fair Representation.

Few surveys go wrong because the sample is not large enough. Many go wrong through a faulty selection of the sample. To give reliable results a sample must be representative of the population from which it was taken. As a general rule, ignoring more recent sampling developments, every individual in the population must have an equal chance of being included in the sample. A conspicuous example of failure to observe this rule was the Lanarkshire Milk Experiment. Instructions were given to list schoolchildren alphabetically, and free milk was to be given to pupils picked at regular intervals from the list. Their increase in weight and height was then to be compared with that of a comparable group of children who were not to be given free milk. Unfortunately, teachers were given some discretionary powers in selecting the children and, as might have been expected, they tended to push badly-nourished and under-weight children into the free milk group. Thus, though they helped these children they defeated the purpose of the experiment: it did not show the average effect of the issue of free milk but the effect of the issue to particularly under-nourished children. The pupils on a more adequate diet did not have the same chance of being included in the experiment.

A more subtle infringement of sampling rules lay in an instruction given to investigators in a local survey to pick out the first house in each street, and then every tenth house. Publicans and shopkeepers tend to be found more frequently in corner houses, and where such an instruction is observed they will be over-represented in the sample.

The selection of the sample should as far as possible be taken out of the hands of the investigator and concentrated at headquarters where a random sample can be more easily laid out. Detailed rules of selection are somewhat too technical to be discussed at length here.

External Checks.

Checking the result of the selection, and ascertaining whether the sample is representative or not, is fairly straightforward. Thus, opinion surveys should include factual questions such as whether the contact is a trade-union member, or whether his family owned a car before the war. The percentages obtained can then be compared with the known statistics to see whether trade-union members, or pre-war car-owning families, are accurately represented in the sample. The statistical blackout which—along with the other one—is now being lifted, has rendered such checks rather difficult under war-time conditions, but even before the war the paucity of statistics in Great Britain was a serious handicap. It is widely recognised that the quality of the work done in sampling surveys depends to a considerable extent on the comprehensiveness and availability of the census statistics.

It may happen that samples which were carefully selected initially become unrepresentative as the survey proceeds. There are always people, rather unpopular with those responsible for carrying out a survey, who refuse to co-operate by giving desired information. As long as the rate of refusals is very low, no danger can arise. It may be, however, that the refusals are related to a particular answer, and their exclusion from the inquiry would then affect the result. In a sample investigation on saving, it is probable that high savers would show a greater rate of refusals than low savers; as it has been put, "thrift and secretiveness may be correlated." This consideration serves to underline the need for a careful application of external tests to guard against the danger of accepting a sample which is unrepresentative either because of faulty selection or because of the high rate of refusals.

Internal Checks.

Another problem on which much research has been done is that of interviewer's bias. However carefully investigators are selected and instructed, they remain human beings and their likes and dislikes, even with the best endeavour to remain objective, cannot fail to affect the answers they obtain. This applies particularly to the interview inquiry and is one of the fundamental objections to "open interviews." The term "open interviews" applies to the technique whereby the interviewer is given no set questionnaire but is given instead a list of topics on which the views of the contact are to be sounded or factual information is to be obtained. It is left entirely to the discretion of the interviewer as to what is or is not recorded. Inevitably selection occurs, and there is no reliable method of controlling the selection.

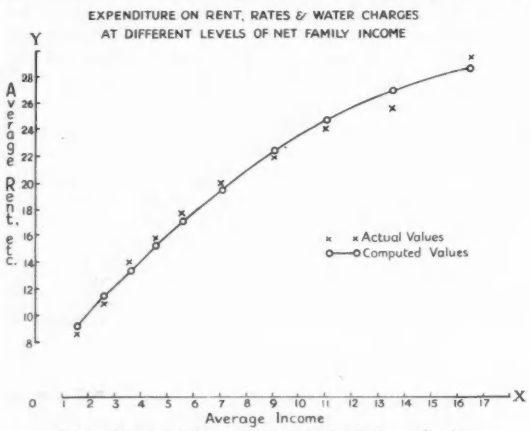
The impact of the interviewers' bias can be reduced through headquarters deciding beforehand on the range of answers which are desired, that is, by "pre-coding" the answers (see the questionnaire reproduced in the illustration). Just as selection of the sample should be taken out of the hands of the interviewers as far as possible, so should the selection of answers.

A sound rule that helps to minimise the dangers of bias is not to rely on only a few investigators. It is also advisable to choose them from different social strata. This procedure will, of course, not eliminate bias but it is likely to introduce biases in opposite directions, and with a large number of investigators some of the errors will tend to offset each other. Using a large number of field workers has the additional advantage that it reduces the number of interviews each field worker has to obtain, thus avoiding the danger that the interviewing becomes mere routine.

A scientific method of ascertaining interviewers' bias is to tabulate the results separately for each interviewer. Differences in their results may be due to (*a*) regional differences between the places where the investigators

[1] The final figures were published in the *British Medical Journal* of August 5, 1944.

worked, (*b*) chance fluctuations of sampling, (*c*) interviewer's bias. It is feasible to make a rough allowance for (*a*) by grouping interviewers who worked in the same or similar areas, and it is also possible to isolate the effect of (*b*). If a difference now remains which cannot be explained by either of the first two factors, bias on the part of the interviewer is at least indicated and a detailed examination of his results may give further proof of it. The technique used is similar to that of Statistical Quality Control in industry; the purpose is, of course, the same,



The characteristic pattern obtained by plotting average rent against average income for various income groups. It approximates to the curve for the equation $y = 5.9 + 2.34x - 0.06x^2$, where y is average rent in shillings per week and x is average income in £ per week. A stable sample if broken down into income groups should yield a regular pattern of this type.

to segregate random fluctuations from fluctuations due to systematic factors, in this case the interviewer's bias.

This kind of test amounts to a check on the internal consistency of the sample. Whenever a sample is split up into subordinate elements, its inherent stability may be checked. If, for instance, average rent paid by different income groups is plotted against the average income of each group, the sample, if sufficiently large, should show a characteristic pattern, rent rising fairly regularly as income increases. It should be borne in mind, however, that a sample may be internally stable even if it is not representative, even if it excludes partly or wholly some strata of the population from which it was taken.

Question Wording.

The principle that questions should be completely neutral, that they should not give a lead one way or the other, is commonly understood. It is not always so easy, however, to decide in any given case whether this rule has been infringed. Critics of a questionnaire who hold strong but opposing views on the subject matter of an inquiry will sometimes agree that a question is biassed, but for different and mutually exclusive reasons. As it has been put by a critic on one occasion, "Bias may be so subtle that one sometimes is not sure oneself whether it is there or not."

There is, however, an objective test. If it is suspected that the phrasing of a question is biassed and if another wording is suggested, a pilot survey should be taken using what is called "the split ballot technique." The sample is divided into comparable sub-samples, and each sub-sample is asked one of the versions of the question. To safeguard comparability a control question is also included for each sub-sample. If apart from chance fluctuations due to sampling, the sub-samples give similar results, the suspicion of bias in the wording of the question may be safely dropped.

Questions should, of course, be phrased in such a way that all the factual information relevant to the problem in hand will be obtained. In practice it is sometimes difficult to know what may be relevant, unless a pilot survey has been taken. In an inquiry whether people used Anderson shelters, the percentage claiming to have shelters was too high compared with the actual issue. The explanation was that a supplementary question ought to have been asked whether families having shelters shared them with other families. In such matters experience is the only teacher and mistakes the schooling fee that has to be paid.

There are some questions which ought never to be asked directly, for instance, questions involving prestige. The stronger the social pressure in favour of a certain attitude or behaviour, the more difficult it is for a survey to establish the extent to which the pattern is actually complied with. No survey has yet succeeded in estimating the proportion of people going to church on Sundays by simply asking the straightforward question. Investigations of newspaper readership based on the question, "Which paper did you see yesterday?" tend to reveal a proportion of *Times* readers which is considerably larger than circulation figures would warrant, even after one has allowed a relatively large number of readers to each copy sold. If, on the other hand, a question is asked about the subject of last Sunday's sermon or if the interviewers go around with yesterday's daily papers asking contacts which features they found of special interest, a correct picture is more likely to be obtained. The questions must be as concrete as possible and information must be sought in the form which most readily lends itself to checking.

Questions on public opinion may sometimes yield misleading results unless they are correlated with the relevant facts. Thus, in an inquiry aimed at discovering whether the public preferred living in houses or in flats, only a small minority was obtained in favour of flats. When, however, the results were analysed according to the type of dwelling the contact was living in, it was found that a considerable proportion of flat dwellers was in favour of flats. It was those who had no experience of flats who were most in favour of houses.

The Rare Confirmation.

Survey results are—or ought to be—new knowledge; ordinarily no direct check on the result is possible. Election forecasts are one of the rare exceptions. If in a single instance the election result tallies with the forecast, the agreement may, of course, be fortuitous. On the other hand, the six by-election forecasts made by The British Institute of Public Opinion before the war showed an average difference between predicted and actual percentage of less than 3%, while the difference in no case

exceeded 6%; this record may be accepted as convincing proof of the soundness of the methods used.

There are cases where the figure of national expenditure on an item, say, that on rent, is already known and the purpose of a survey is to establish the variations at different income levels. The sub-totals thus secured must in the aggregate agree with the national total which is already known.

Results can sometimes be checked against the outcome of an inquiry carried out independently by another organisation. When the results of a British Institute of Public Opinion survey of newspaper readership carried out in the summer of 1944 were being computed, it was of interest to compare the figures, as they became availabel, with the results of a similar War-time Social Survey inquiry which had been made a year earlier. Both sets of figures were in general agreement, the British Institute of Public Opinion results tending to be 2-4 percentage points higher than those secured by the War-time Social Survey. The difference arose from increases in circulation and special interest in news due to the Second Front. This example also brings out the need for co-operation and mutual criticism in what is, after all, a new field of scientific research.

The Social Background.

Social surveys in their present form—the term has now become practically synonymous with sample investigations of social conditions—do not date back farther than the beginning of the century. Reading can claim to have been the first place where a survey on the modern principle of random sampling was carried out; in 1912 Professor Bowley undertook a survey on the economic condition of the town's working class. Yet the underlying principles are much older. The theory of sampling was established three hundred years ago. As far back as the French Revolution a sample survey was actually carried out. Its purpose was to estimate the total population of France from the known number of births per year. By selecting a number of typical "Departments" and carrying out a census in these Departments, the birth rate could be computed for the sample areas, and applying it to the total number of births in the country a fairly good estimate of the total population was obtained.

In the development of survey methods the fundamental unity of science has again been demonstrated; most of the more advanced methods of analysing social data originated in other fields of science, mainly in biology and agricultural research.

The vast majority of surveys have their origin in the needs of administrators to deal with problems which have actually arisen, or in the desire of interested bodies to reveal the conditions which exist. In revealing the nature of those conditions surveys have proved to be one of the agents leading to improvements. An extensive use of social surveys must, therefore, be accompanied by a willingness to face the facts which they establish, a willingness that has regrettably not always been present.

Especially during war-time there is much valuable knowledge gained through surveys which does not see the light of day. If the policy were followed of publishing every piece of work which could possibly be published, not only would the information thus disseminated be useful but through growing familiarity with this type of investigation, the distrust with which it is still regarded in some quarters would be dispelled.

READING LIST.

Apart from fairly advanced but widely ignored developments in U.S.S.R., the theory of sampling and its applications to social problems has been—to a large extent—worked out by British statisticians. It is dismaying, therefore, to find how sparse is the British literature dealing with the aspects we have been discussing. The works in Section A are ranged in order of increasing difficulty.

(A.) *Methods.*

A. L. BOWLEY. The Application of Sampling to Economic and Sociological Problems. *Journal of the American Statistical Society, September*, 1936. (Non-mathematical treatment of the development and use of sampling).

L. H. C. TIPPETT. Statistics. Home University Library, 1943. (Introductory book for the general reader).

F. C. MILLS. Statistical Methods. Pitman. (Reprinting). (Introduction to statistical methods, both elementary and more advanced).

G. U. YULE and M. G. KENDALL. Introduction to the Theory of Statistics. Griffin, 1937. Chapters 18 to 21. (Full treatment of theory of sampling).

A. L. BOWLEY. Elements of Statistics. King, 1937. Part II, Chapters 2 to 4.

(B.) *Reports on Recent Work.*

P. ADY. The Statistical Background of Clothes Rationing. *Oxford Bulletin of Statistics*, 1944 (*Nos.* 13 to 15).

HADLEY CANTRIL and others. Gauging Public Opinion. Princeton University Press, 1944.

HENRY DURANT & J. GOLDMANN. The Distribution of Working-Class Savings. *Oxford Bulletin of Statistics*, 1945 (*No.* 1).

J. GOLDMANN. Expenditure on Rent. *Oxford Bulletin of Statistics*, 1944 (*No.* 11).

"The Lighting of Buildings," Ministry of Works. Post-war Building Studies, No. 12, (containing a report by War-time Social Survey).

CHARLES MADGE, War-time Pattern of Saving and Spending. Cambridge University Press, 1943.

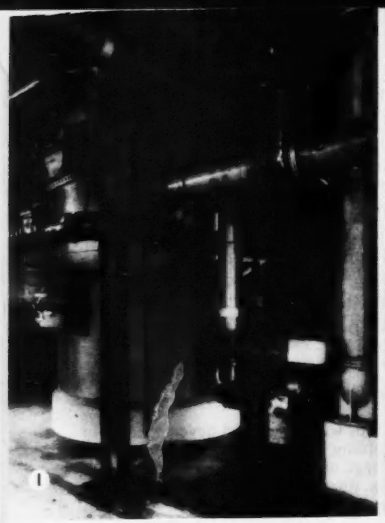
"Some Significant Aspects of Community Development." (A report by War-time Social Survey). Appendix E to Report by Scottish Housing Committee on Distribution of New Houses in Scotland, Stationery Office, Comd. 6562.

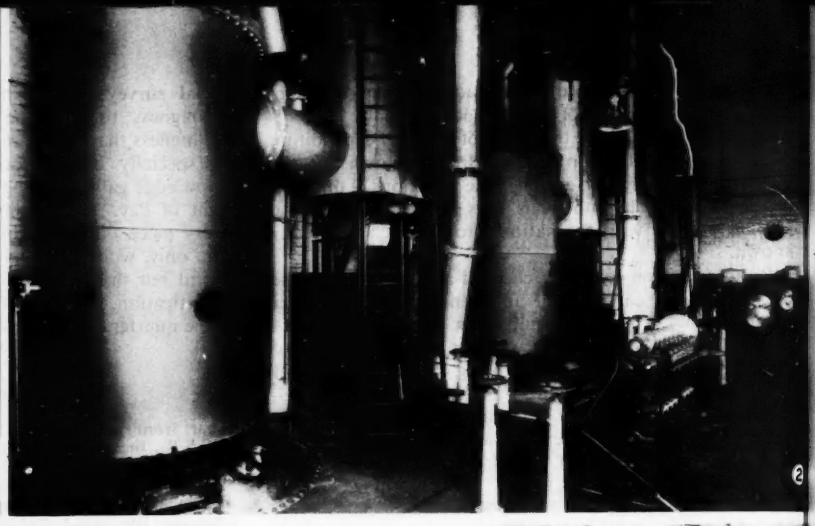
R. J. E. SILVEY. Methods of Listener Research Employed by the B.B.C. *Journal of the Royal Statistical Society*, 1944.

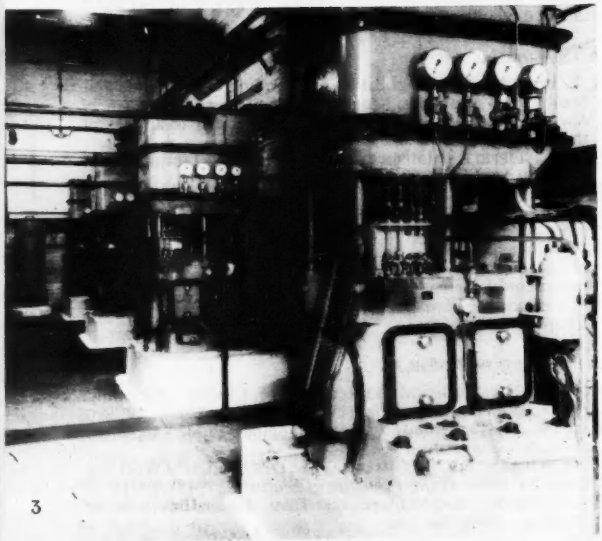
PERCY STOCKS. Health Survey. *Monthly Bulletin of the Ministry of Health, April, May, June*, 1944.

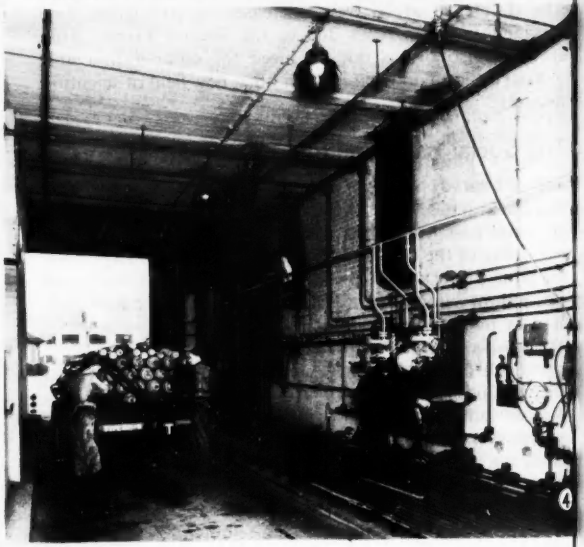
GEOFFREY THOMAS & KATHLEEN BOX. The War-time Social Survey. *Journal of the Royal Statistical Society*, 1944.

F. C. WHEELER. The Technique of Market Research. McGraw-Hill, 1937.









This plant for generating hydrogen required for barrage balloons is run by a gasworks in the south of England.

1. This photograph shows the ground floor of the generator house: one generator and the connecting mains can be seen.

2. The operating floor of the generator house, showing mechanical operating gear. Automatic operation is achieved by means of a series of cams; these rotate and cause rods to move which operate the valves.

3. The purified gas is stored in a gas-holder and then passes to the compressors. In 4 stages the hydrogen is compressed to 3000 lbs. per square inch.

4. The charging bay, where 4 road vehicles or 2 railway trucks plus 2 road vehicles can be loaded at the same time. The cylinders are seen being charged with gas.

5. The cylinder testing plant. The girl is examining the interior of a cylinder by means of an instrument called an introscope.

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The most concentrated barrage was that put up in the defence of London against the flying bombs. Nearly 2000 balloons were flown behind the fighter and A.A. gun belts. They brought down 279 V1's, 15% of all that entered the balloon zone.

Hydrogen for the Balloon Barrage

THE R.A.F.'s Balloon Command has been disbanded though apparently balloons will continue in use for the protection of smaller targets.

It is likely, however, to be a long time before any critical assessment of the contribution that the Balloon Barrage has made to air defence—the contribution to the air defence of cities is particularly controversial—becomes available. On two aspects, however, judgment is already possible and praise already due. Firstly, the balloon crews have done well an almost demoralisingly dull job. Secondly, there has been the technical achievement of providing the enormous quantities of hydrogen required for inflating the balloons. It is with that accomplishment that this article is concerned. When one considers the fact that hydrogen plants were developed with a total capacity of 40 million cubic feet of hydrogen a week one begins to realise the magnitude of the achievement and to see that it stands favourably in comparison with what the Germans have done in a not dissimilar field, namely the production of liquid oxygen for the V2 rocket.

The maintenance of the Balloon Barrage required hydrogen far in excess of the amount normally obtainable from industrial sources. The supply position early in the war was rendered the more difficult since the particular industries which use hydrogen or produce it as a by-product and were therefore our main supply source when the war started are mainly located in the north of England, many miles from where the main concentrations of balloons were required in the Battle of Britain. The limit imposed by transport from the north was reached as the enemy brought the air attacks on southern England to a crescendo in 1940. It became necessary to fly, as an emergency measure, the barrage with some coal gas in the balloons, although this reduced operational efficiency somewhat. To meet the critical hydrogen shortage and to cover the further expansion of the Balloon Barrage it was decided to create at short notice a new source of supply which would combine the following requirements: (a) the need for dispersal, so that the risk of damage by enemy activity could be minimised (b) the necessity of the factories to be near to the using centres in order to reduce the transport problem and (c) flexibility of output to meet a demand that is bound to fluctuate according to the amount of enemy action and the vicissitudes of weather.

The Directorate of Hydrogen Production, set up by the Air Ministry in September 1940, settled upon a policy which depended for its success upon the widespread operation of what is called the steam-iron process. This method of preparing hydrogen requires as its raw materials steam and water gas, the latter being the mixture of carbon monoxide and hydrogen produced at gasworks for admixture with coal gas. Steam-iron plants at gasworks were already under construction at gasworks in September 1940 (indeed the first of these plants went into operation in that month) but the Air Ministry proceeded with plans to build many more such plants, of a smaller type and with a greater degree of dispersal, a measure calculated to serve better the supply needs of the barrages and to make more difficult for enemy bombers serious interference with production.

The effect of this policy upon the ratio between hydrogen from gasworks and hydrogen from other sources can be seen from the table; in 1940 only about 7% of the total hydrogen supply came from gasworks, whereas in 1944 the percentage had risen to over 70%.

Year	*Production at Gasworks*	*Other Sources*
1940	43,060,440 cu. ft.	545,510,249 cu. ft.
1941	304,906,600 ,,	434,380,900 ,,
1942	452,193,900 ,,	316,248,600 ,,
1943	541,764,600 ,,	265,567,900 ,,
1944 (9 months)	431,806,800 ,,	157,602,000 ,,
	1,773,732,340 cu. ft.	1,719,309,649 cu. ft.

HYDROGEN SUPPLIED TO BALLOON BARRAGE

The Balloon Barrage has thus been supplied from two sources: (a) the industries which produce hydrogen either as an intermediate or as a by-product (for instance

the caustic soda-chlorine industry, and (b) the gas industry, by means of the steam-iron process. Steam-iron processes were considerably developed in the Great War; in Britain the Lane process, devised in 1903, was much used for producing hydrogen for military purposes, while the Germans relied upon the Messerschmidt process, invented in 1913.

The techniques used in Britain during this war represent a further advance, though the fundamental chemistry involved is the same. The steam-iron process proceeds by stages. In the first, water gas (which is a mixture of hydrogen and carbon monoxide prepared by splitting water by means of hot coke) is passed over spathic iron

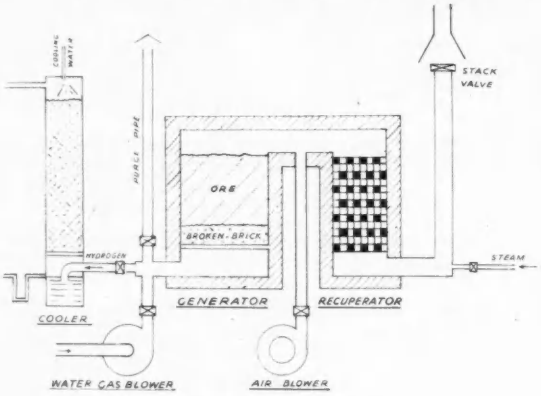


FIG. 1

ore (Fe_3O_4) at a temperature of 900-1050°C. This leads to the iron ore being reduced to a lower oxide, both the carbon monoxide and hydrogen contributing to the reduction according to the two following equations:

$$CO + Fe_3O_4 = CO_2 + 3\,Fe\,O$$
$$H_2 + Fe_3O_4 = H_2O + 3\,Fe\,O$$

A slight amount of ore is still further reduced, to metallic iron. The two reactions indicated above are reversible, and there is always some unchanged hydrogen and carbon monoxide in the final mixture of gases that results when equilibrium is reached. High temperatures carry the reactions towards the right, i.e. they favour the reducing action, but a practical limit is encountered in this connection since the ore itself tends to fuse above 1100° C. The spent reducing gas left after the reduction stage is burnt with added air in a recuperator and so provides the heat necessary to maintain the process.

After a time, the supply of water gas is shut off. In the second stage, steam is superheated by passage through the recuperator, whence it passes through the reduced iron ore to yield hydrogen; at the same time the iron ore is restored to its original state. The reaction can be shown by the equation:

$$H_2O + 3\,Fe\,O = Fe_3O_4 + H_2$$

This reaction also does not proceed to theoretical completion, and is adversely affected by high temperature. The outgoing hydrogen always contains a considerable proportion of undecomposed steam which, however, is easily removed by cooling. The crude hydrogen passes through a washer-cooler into a relief gas-holder, from which it is pumped through a purifying system (to remove hydrogen sulphide and carbon dioxide) and into the storage holder.

In the original Lane process, the iron ore was contained in retorts that were heated from the outside (the heat being generated either by burning coke or spent gas). In the Messerschmidt plant, the heating gas was burnt actually in contact with the ore, and development of the steam-iron process since has all been towards supercession of the externally heated type by internally heated ones. In principle these are all similar, consisting of a brick-lined steel vessel, *the generator* (see Fig. 1), which contains the ore that rests on a layer of broken brick; the generator serves to pre-heat the reducing gas. *The recuperator* consists of a cylindrical vessel filled with chequer brick; it may be mounted on top of the generator, or alongside it (as in Fig. 1), or it may be placed in the centre of the generator with the ore occupying the annular space between the wall of the recuperator and the brick-lined shell (as in Fig. 2). With a plant such as that shown diagramatically in Fig. 1 (the essential valves for the control of the operations are indicated) the whole cycle of reduction and steaming is carried out in 10 minutes, 5 to 6 minutes are taken by the reducing stage, this is followed by a short purge with steam (10 to 30 seconds), and the remainder of the cycle is occupied with the steaming stage. With a relatively long cycle of this kind the valves that control the process can be operated by hand, but automatic control has been perfected for some of the plants, one of which is pictured in the photographs.

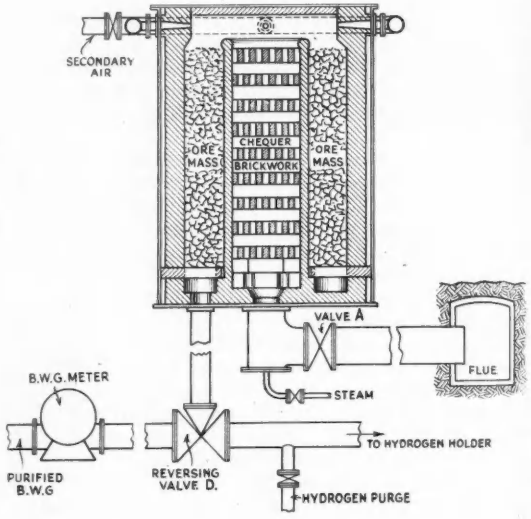


FIG. 2.—By permission of the editor of *The Chemical Age*.

Night Sky in March

M. DAVIDSON, D.Sc.s F.R.A.S.

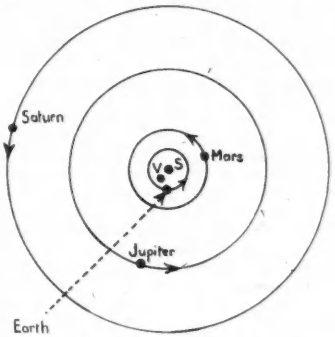
The Moon.—New moon occurs on March 14d. 03h. 51m. U.T., and full moon on March 28d. 17h. 44m. The following conjunctions take place:

March				
11d. 21h.	Mars in conjunction with the moon	Mars	2	N.
16d. 10h.	Venus ,,	Venus	12	N.
21d. 03h.	Saturn ,,	Saturn	0.4	N.
27d. 05h.	Jupiter ,,	Jupiter	3	S.

The Planets.—At the beginning of the month, Mercury is close to the sun, rising 20 minutes after and setting 10 minutes before sunset. At the end of the month the planet sets at 20h. 09m., about 1h. 38m. after sunset. Mercury attains its greatest easterly elongation on March 26. Venus is conspicuous in the evening, setting at 21h. 45m., 21h. 52m., and 21h. 04m. at the beginning, middle and end of the month respectively. The greatest brilliancy of Venus occurs on March 10.

Mars is a morning star but is too near the sun for favourable observation. Jupiter, in the constellation of Virgo, a little north of β Virginis at the beginning of the month, moves into the constellation of Leo before the end of March. The planet can be seen throughout the night, rising at 18h. 49m. and 16h. 24m. at the beginning and end of the month, and setting at 7h. 26m. and 5h. 17m. on the same dates. Between these dates the distance of Jupiter from the earth varies from 416 to 427 million miles. On March 13 Jupiter is in opposition to the sun. Saturn, in the constellation of Gemini, near μ Geminorum, sets at 3h. 47m. and 1h. 53m. at the beginning and end of the month respectively, and is stationary on March 5. The distance of Saturn from the earth varies between 798 and 844 million miles on March 1 and 31.

The relative positions of the planets are shown in the diagram, the middle of March being assumed as the date. The scale is so small that the full orbit of Venus has not been shown but the position of the planet on March 15 is indicated by the letter V. Venus does not appear brightest when she is nearest to the earth because in this case, as she would be between the sun and the earth, her appearance would be like that of new moon-a crescent. When Venus is on the side of the sun remote from the earth she appears like full moon and it might be thought that in these circumstances she would be brightest, but as she is at her greatest distance from the earth at this time, and as her brightness varies inversely as the square of the distance, her brightness does not attain a maximum then. A simple mathematical investigation shows that Venus is at her brightest when her elongation (the angle at the earth contained by the lines Earth-Venus and Earth-Sun) is about 40°.



Relative positions of the planets on March 15. The sun is denoted by S and Venus by V.

The diagram also shows why Mars is not favourably placed for observation, being too near the direction of the sun as seen from the earth, and also why Jupiter is in opposition to the sun on March 13, the sun, earth and Jupiter being then in a line. On March 5 the earth is moving away from Saturn, as the diagram shows, and hence Saturn appears stationary.

Some readers may consider it remarkable that Venus is in conjunction with the moon on March 16d. 10h., and yet is 12° N. of the moon. When a planet is in conjunction with the moon this implies that their right ascensions are the same but their declinations may be very different. At the date and time referred to the right ascension of Venus is about the same as that of the moon, but the declination of Venus exceeds that of the moon by about 12° then.

Venus can scarcely be mistaken as she can be seen like a very brilliant star in the west after sunset.

Vernal Equinox is on March 21d. 00h.

Some readers have enquired about Star Charts, etc., to assist them in finding the stars and planets referred to. Philip's *Chart of the Stars* by E. O. Tancock will be found very useful for this purpose.

M. DAVIDSON, D.Sc., F.R.A.S.

JUNIOR SCIENCE

Light and Colour

LIGHT is one of the most important things in our life, but until fairly recent times the actual process by which light is generated has remained a mystery. Even to-day, while we know a good deal about the sources from which light emanates, we are aware that our conception of the origin of light provides an inadequate model.

Light is, like radio waves and heat waves, an electro-magnetic radiation. In order to produce such a radiation, electricity must oscillate, that is, move to and fro like the swing of a pendulum or the vibration of a spring. Such an oscillation of electricity occurs in the aerial of a wireless transmitter, and the electrical dimensions of the aerial system determine the wavelength and the frequency—frequency is the number of oscillations per second—in the same way as the time it takes a pendulum to complete a swing depends upon its length.

The only difference between light waves and radio waves is that light waves are very much shorter. Whereas the length of the usual broadcasting waves is about 300 metres that of light is only about 2/100,000 inches. This shows that the dimensions of the "aerial" which produces the light waves must be very much smaller than those of the radio aerial. And that is quite true, for the light waves are produced inside the atom. For this reason we know very little about the generation of light.

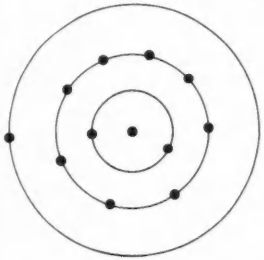


Diagram indicating how the electrons are arranged at different distances from the nucleus of the Sodium atom. The electrons revolve in orbits lying in different planes.

Scientists have made a rough mechanical model of the atom in which the electrons, minute particles bearing a negative charge, are supposed to circle around a positively-charged centre or nucleus like the planets around the sun. When the atom receives energy, as may happen, for instance, if it collides with another atom, an electron will be pushed out of its orbit and become farther away from the nucleus, only to return to its old place an instant later. This movement of electricity inside the atom is the origin of light waves.

Red light has a long wavelength compared to blue, and in between come orange, yellow, green. The light of the sun and that emitted by an electric bulb is a mixture of all colours, but by using one particular kind of atom under certain conditions we can produce "monochromatic" light—light of one particular colour or wavelength. For instance, if you dissolve some ordinary table salt (sodium chloride) in a little water, dip a bit of asbestos into this solution and then hold it in a gas flame, the sodium atoms will emit monochromatic yellow light. Study the appearance of objects of different colour in this light. Other atoms emit monochromatic light of other wavelengths. Copper wire brought into a gas flame will colour it green.

K.M.

The Bookshelf

The Royal Society 1660 to 1940: A History of its Administration under its Charters. By Sir Henry Lyons, F.R.S. (Cambridge University Press, 1944; pp. x + 354; 25*s*.).

THE subject, the *administration* of the Royal Society, by its very nature precludes the book from being easily readable, and from being interesting or instructive when taken alone. As Sir Henry Lyons himself says, it "will provide the groundwork for a fuller discussion of its (the Society's) influence on the advancement of science". It is therefore best considered as a reference book for the historian of science. As such, it contains a most valuable collection of material, which will not only provide the historian with the facts he requires, but also suggest many profitable lines for further research.

As a reference book, however, it is unfortunately marred by several faults of arrangement and presentation. The order in which topics are discussed is often confused. An example is worth giving. Under the heading FINANCE, pp. 126 to 129 discuss that subject. Subsequent pages then contain the following miscellany: 130, various administrative matters, the Society's neglect of technology in the eighteenth century, more finance; 131 to 6, accommodation; 137, more finance, circumstances of delay in printing Newton's *Opticks*, election of Prince George of Denmark to Fellowship and his aid in publishing Flamsteed's star catalogue; 138, new regulations to ensure payment of subscriptions, and so on. Again, on p. 90 Oldenburg's biographical details are given, only at his death, after 26 previous references to him. There is much needless repetition, which might well be replaced by more thorough cross-referencing. The index needs considerable improvement. It requires the addition of such subject headings as "connections with other bodies" and names of countries and towns.

Many of the index headings rebuire more analysis; 90 odd-references under "Council of the Royal Society", without sub-division, is hardly satisfactory. Many items remain unindexed; for example, the most important quotation from Bishop Sprat's history on p. 52, or the reference to the International Research Council on p. 317. Though the text of the second Charter is given in an appendix, there is no reference to this in the relevant portions of the text on pp. 36 to 39. Another appendix gives various useful statistical analyses for selected years up to 1860; some of the statistics are completed for later years in the text, but reference would be much facilitated if all were gathered in the appendix. The bibliographies attached to each chapter are good, yet there are some notable ommissions, such as M. Ornstein's, *The Role of the Scientific Societies in the Seventeenth Century*. The usefulness to the historian would be greatly improved by specific references to such sources as the Minute Books.

Finally, it would surely be possible for the Cambridge University Press to provide better quality paper for so important work.

These criticisms may seem trivial. They would be so indeed if the book were of lesser importance but, since the material therein is so extremely valuable and has obviously been collected only with great trouble, it is a pity that its accessibility should be reduced by mere faults of presentation. It may be assumed that Sir Henry Lyons would have wished to revise the work so as to eliminate these weaknesses, but was prevented by the ill-health of his last years. A second edition, based on his material but with revised presentation, would be a fitting tribute to his life's work.

Sir Henry rarely leaves fact for the more adventurous ground of interpretation. When he does so he is less happy. Few would agree that "throughout the history of the Society we find that its scientific reputation was created, maintained and advanced by quite a small number of Fellows who were endowed with exceptional talent and scientific foresight". This is undoubtedly true for some periods, but to assert it in general is not only to ignore the immense importance of the corporate activities of the society (of which many examples are given), but also in fact to deny the importance of the Society as a body. Could these Fellows have achieved their successes without the opportunities for discussion, the facilities for publication and the scientific atmosphere which the activities of the Society created?

One axe is ground consistently throughout the book—the thesis that the early troubles of the Royal Society were due to the fact that its membership was not confined to scientists, and that the situation reached in the last century, when the membership became almost exclusively scientific, is the ideal. The evidence produced to back this theory is not satisfactory. The most important element is the fact that in the 18th and early 19th centuries, when the Society was at a low ebb, its non-scientific membership was considerable and that the exclusion of non-scientists and the revival of the Society occur in parallel in the latter part of the 19th century. Such a simple correlation is no evidence of direct causation—a common cause for both phenomena is an equally likely explanation—while the fact is ignored (for the purposes of this argument) that non-scientists predominated from 1660 to 1700, the Society's most brilliant period except possibly for the last forty years. Other evidence produced is flimsy—for example, the fact (twice repeated) that Banks recommended Wollaston, the chemist, as his successor is interpreted to mean that Banks believed a scientist president to be essential to the welfare of the Society.

The contrary thesis is ignored—namely that the degeneracy of the Society in the 18th century was due largely to the fact that it had abandoned its early interest in the technological as well as fundamental aspects of science, had thus lost touch with the most advanced parts of science and so had lost the support of many of the greatest scientists; and the complementary conclusion that, though the present state of the Society is much better than at any time since 1700, nevertheless it could be further improved by closer contact with (if not the admission to Fellowship of) some who are interested in the furtherance of science from the point of view of users. To suggest that only scientists have an interest in the progress of science is to condemn science as a private amusement. Some of the evidence for this thesis is there in factual form, but is not commented on—the 18th century loss of interest in technology; the fact that Newton could have got rid of the non-scientists but apparently did not think it wise to do so; and the fact that Grove found it more appropriate to communicate the first description of the "Grove cell" to the British Association, apparently because that body was more likely to value correctly a contribution to the *modern* science of electricity. Much other evidence is naturally not present, since it is not required for the main purposes of the book—the non-membership of many prominent scientists in the degenerate period; the failure of the Society (even though it had become almost entirely scientific) to appreciate and publish Joule's paper on the heating effects of an electric current, and Joule's own comment, expressing so eloquently the gulf between the Royal Society and the manufacturing North, "I could imagine these gentlemen . . . saying to each other: "What good can come out of a town where they dine in the middle of the day?"—all of which tend to show that the Society's state arose from its contempt for technology and consequent lack of appreciation of the really progressive aspects of science.

However, the author is entitled to his interpretations, as the critic is to his, and no amount of disagreement on these matters can diminish the immense value of the factual material stored in this book.

S. LILLEY.

Edward Sylvester Morse. By Dorothy G. Wayman. (Harvard University Press, 1942; Humphrey Milford: pp. 457, 25*s*. 6*d*.).

ITS blemishes are so trivial that this book is an almost perfect biography. It will have a wide readership, though one needs some slight knowledge of biology to get the best out of it. E. S. Morse, it should be pointed out, was the American biologist who died in 1925. The portrait Mrs. Wayman has painted is that of a whole man, it is not an X-ray projection of the different parts of a puppet swept like a cork on a sea of economic troubles. For the reason that the approach is simple (though never naive) it is refreshing.

WM. E. DICK.

Far and Near

Institute of Medical Laboratory Technology

IT has been brought to our notice by several readers that the Pathological and Bacteriological Laboratory Assistants' Association (mentioned in the December issue of DISCOVERY in a note entitled "The Technician in the Laboratory") has since the war started been taken over by the Institute of Medical Laboratory Technology. This body, which has a membership approaching 2000, received its certificate of incorporation in November 1942. Its functions resemble those of the professional scientific institutes. There are four classes of members—students, ordinary and associate members, and fellows—entrance to all of which is by examinations set by the Institute. The examinations, and the tutorial courses for them, are arranged in all centres where there is a demand. The body, which has close liaison with the Pathological Society and the Association of Clinical Pathologists, has applied for a Royal charter. It is considering an extension of its functions in order to cover personnel engaged in experimental physiology and biology and all medical laboratory workers.

Technical Advice and Agricultural Teaching

WHILE there is a great need for agricultural research to be encouraged, there is a still greater need for the information already revealed by scientific investigation to be passed on to farmers in a palatable and digestible form. This point was well brought out at a recent Ministry of Agriculture press conference by Mr. G. A. Holmes, a New Zealand grass-improvement expert, who for the past 2½ years has been working under the Wilts War Agricultural Executive Committee and who is shortly returning to his own country. "In agricultural education and research I think there is a great field for the future," he said. "Although the war has helped development, agricultural education and research is too academic. In many lines of research worker and the farmer, with world and I feel that in agricultural research British scientists have done much of the fundamental work but it has not been translated yet into farming practice. You want a liaison between the research worker and the farmer with field trials, common sense, simple and practical things the farmer wants to know. Farming has got to change; it cannot live in the economic conditions of the past". Speaking at the same conference another New Zealander, Mr. A. Johnson, an animal-husbandry officer, said there is a definite gap between research and the farming community, which has not yet been bridged successfully.

In his recent address to the Jubilee Meeting of the Agricultural Education Association held in London, the Minister of Agriculture referred to the prospects of the National Agricultural Advisory Service. He mentioned Professor J. A. Scott Watson's appointment as head of the Service and the filling of several senior posts at headquarters; these men will be largely responsible for working out a detailed scheme. Mr. Hudson disagreed with those who thought such an advisory service would make it unnecessary for prospective farmers to undergo a scientific training in agriculture. If agriculture was to be progressive, if farmers were to be in a position to take advantage of the latest scientific developments, then Britain must ensure that the men and women entering the industry were trained and educated in the science of agriculture. It would be the job of the advisory service thereafter to keep them up-to-date. He believed that the future of British agriculture would depend more than anything else on the ability of our farmers to produce food at prices bearing comparison with the prices of food imports, but this would be dependent on our being able to make use of all the latest scientific discoveries.

Mr. Hudson declared that he was anxious about the present great scarcity of good technical men. "There is a great gap to be filled before we can satisfy the demand that there will be for men to carry out the jobs that face us after the war. We must have men for the Advisory Service; men to teach the older students at the Universities and Colleges; men to teach the younger students at the farm institutes; men to instruct the large numbers of ex-servicemen and women whom we are going to train when the war with Germany is over; men to staff the research stations, etc. Men with an expert agricultural training will also be wanted by commercial firms, by the Colonial Agricultural Service and in other fields. It means, therefore, that for a time we may find it difficult to push on as rapidly as we would like with all the plans that have in mind. For first we shall have to teach the teachers," he commented.

Last month other appointments to the Ministry's advisory service were announced. The following senior education and advisory officers have been appointed: Mr. F. Rayns, Dr. W. K. Slater and Dr. H. V. Taylor.

Science in Industry

OF the speeches made at the British Association's recent conference on "The Place of Science in Industry", Professor P. M. S. Blackett's was the most provocative and appeared to rouse the audience more than any other. After describing fundamental research as being in the nature of a long-range investment, whereas applied research is a short-term investment, he pointed out that in most subjects, more particularly in physics but less so in biology, the fundamental science carried on in the universities had ceased during the war. This had been done by moving the personnel on to applied research, a deliberate sacrifice of long-period dividends to short-period gains. In the period 1939-41 there was no question but that this was the right policy, for the development of industrial processes and weapons could not be delayed. It was not right simply because there was a war on; it was right because it was thought that the war would be a short one. To disturb the balance between fundamental and applied science was serious in a long war. "The war has lasted a long time. We may have slightly over done it. We may have neglected some basic applied work in the interests of directly applicable work. Work done by the enemy shows some deficiencies in our basic applied research", he commented.

The balance between pure and applied science he considered was very important. Fundamental research provided the fundamental knowledge on which further advances of applied science depended. It had another function, being the training ground for the research workers who will fill many of the leading posts in applied science. The country had woken up with a start to the importance of more science, but he thought we ought to look at the position more critically. "Many scientists want to help the world. They have got tired of their ivory towers and really want to do something for humanity," he remarked, adding that a warning needed to be given both th the scientists thinking of entering industry, and to the industrial firms wanting to entice away too many scientists from the universities. The ills of the world, said Professor Blackett, were not going to be cured by professors going "applied". Those ills were due to the crazy working of the economic system.

He anticipated that after the war industry would concentrate on producing more refined radios and wireless sets, instead of aiming at producing greater numbers of all these things. Production must be stepped up, and he would like to see scientific effort and ingenuity being harnessed to the production of *machinery*. That would make possible the production of cheap and durable goods. On the question of certain fields of research being neglected, he thought that something like the Chief of Imperial General Staff's committee was needed, with the power to encourage research in the neglected branches.

Australian Scientific Attaché for Moscow

PROFESSOR Eric Ashby is leaving London for Moscow where he will hold the appointment of scientific attaché, with the rank of counsellor, at the Australian Legation. Professor Ashby, who is professor of botany at Sydney University, is a London graduate. He studied at Imperial College, where he was demonstrator under Sir John Farmer for several years and later lecturer in ecology. During this war he has been chairman of the Australian National Research Council and also honorary scientific adviser to the

Australian Department of War Organisation and to the Scientific Liaison Bureaux. In 1942 he carried out on behalf of the Australian Government a survey of the country's scientific resources.

This appointment of a scientific attache by a Dominion Government has prompted parliamentary questions from two British M.P.'s. The Foreign Office reply was to the effect that the attention of the Foreign Secretary had been called to the appointment. At present there was no comparable officer on the staff of the British Embassy at Moscow. The statement added that at the beginning of last year they suggested to the Soviet Government that a distinguished scientist should visit Russia to discuss with Soviet officials and scientists the improvement of scientific exchanges of a non-military character. The Soviet Government felt, however, that, as many scientific institutions had been removed to different and often remote parts of the U.S.S.R., the visit should be deferred.

Personal Notes

DR. L. S. PENROSE has been appointed to the Galton chair of eugenics at University College, London.

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AIR COMMODORE A. H. ROBSON, M.SC., PH.D., has succeeded to the post of Director of Educational Services to the R.A.F. Aged 52, he has been deputy director since 1942.

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SIR BUCKSTON BROWNE, the well-known surgeon, died on January 19 at the age of 94. Among the scientific world he will be remembered for his benefactions, which he initiated in handsome manner when he made over Downe House and its grounds (where Darwin lived and worked for many years) to the British Association, together with an endowment for its upkeep. He also gave £100,000 for the building and endowment of the Surgical Research Farm of the Royal College of Surgeons, which is situated near Downe House.

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THIS year's president of the British Mycological Society is MR. GEORGE SMITH of the London School of Hygiene and Tropical Medicine.

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AMONG the Dominion scientists who received O.B.E.s in the New Year's Honours List was MAJOR P. L. BAZELEY. A member of the staff of Australia's Commonwealth Serum Laboratories, he joined the Australian army early in the war and was sent to the New Guinea front. When it was decided that Australia should embark upon the production of penicillin, he was recalled from the army and flown to the U.S.A. where he spent some weeks acquainting himself with the technique of manufacturing the drug. Within a remarkably short time of his return, he and a team of workers had succeeded in starting up a small penicillin plant in the Commonwealth Serum Laboratories With the experience gained from this pilot plant it was possible to go ahead with plans for a large-scale plant which is now under construction.

SUCCESSOR to the late Sir J. J. Fox as Government chemist is PROFESSOR G. M. BENNETT, professor of chemistry at King's College, London.

Science for the Citizen—2

LAST month's note on scientific films succeeded in one of its aims for it elicited with encouraging rapidity the information that two films about penicillin will soon be reading for screening in Britain.

From the B.B.C. we learn that it is possible that the first of a series of programmes under the title of "Science Magazine" may go out on March 18. The producer is Francis Dillon, well-known to listeners for his "Country Magazine". It is understood that his aim is to present members of the scientific world to the public in much the same way as he introduced country life to them ; 6.30 to 7 p.m. on Sundays is to be the regular time for this feature, but whether it will be heard every other Sunday, once a month or what had not been decided by the B.B.C. when this note was written.

During the past month there has been little of scientific interest on the B.B.C., except Nesta Pain's programme on yellow fever, which unfortunately no one connected with DISCOVERY heard. We do not feel apologetic about missing it since it went out at 10.40 at night, which does not seem an ideal time for a programme requiring a certain amount of concentration. The B.B.C. inform us that some 2,000,000 "listened" to it (one is never quite with Listener Research figures whether they represent the number of people who happened to have their sets switched on to that particular programme and didn't trouble to turn it off or whether all of the number were really paying attention to what was coming out of the loudspeaker). The listener index for the yellow fever programme, some measure of the interest attracted, was 8.5 %. ITMA, we are informed, rates 30 %.

A reader has drawn out attention to a scientific news broadcast—called "Actualties Scientifiques"—which he happened to hear on the B.B.C.'s service to France —the medium-wave transmission on 373 metres. It began with a short script (lasting about five minutes) by Lord Brabazon on hydro-electric power, which led up to a mention of the Severn Barrage scheme. This was followed by a note on the value of termites as producers of humus, after which came a miscellany of paragraphs—about the Medical Research Council's deaf-aids sub-committees (of rather local interest, one would have thought, and not altogether suitable for export !), idiosyncrasies of human taste, the period of gestation in different animals and the preparation of snake-venom antidotes. It sounds quite interesting, though a bit scrappy. What is remarkable is that the B.B.C. is able to find the time for such broadcasts on overseas services and has yet succeeded in strenuously resisting the demand that items of science news should go out on the Home Service. Perhaps the materialisation of "Science Magazine" will be some consolation to the critics whose opinions have so long been ignored, ostrich-fashion, by th programme builders of Broadcasting House.

A month ago we referred to a naive but by no means innocuous leader that appeared in *The Listener*. It proved to be a hornet's nest and stung several scientists to rebut the charges. As this note goes to press, however, the odds seem to be in favour of the "humanists" winning the argument. Perhaps it is that the editor of *The Listener* really favours the scientist for in the issue of February 1 he indulged himself in that Brains Trust luxury, "second thoughts", and wrote a second leader entitled "More Science?" which should provide a sitting target to anyone with a working knowledge of the English language. In it he produced this exquisite pearl: *Well Doctor Goebbels and Herr Himmler have been applying 'scientific methods to human affairs'*. Which of the countless wrong meanings the word "scientific" has acquired was in the mind of the leader writer when he produced that sentence we are unable to guess. The rest of the leader, we may add, is up to the same high standard, which shows that what the Bishop of Ripon said in 1927 has not been forgotten. One regrets that broadcasters are not allowed the same freedom of expression over the air that the staff of *The Listener* and their correspondents are allowed on paper.

Battlefield Birds

ALBANIA, where units of the British army are now operating, will in time provide scope for the several enthusiastic ornithologists who have already made useful observations on bird-life whilst serving with the 8th Army in North Africa and Italy. They will have the opportunity of confirming the presence of the great black woodpecker which Hugh Whistler first recorded in Albania in 1935. The white wagtail nests along the cliffs and the boulder-strewn shores; marsh-tits, nuthatches and tree-creepers inhabit the Mamuras Forest and the Logra Forest and the rock nuthatch is common in some of the limestone districts. The European and Spanish wheatears, the imperial eagle which nests in the open country below Delvin, the booted eagles of the Logra Forest, the hobbies, the peregrines of Lake Durazzo, the marsh-harrier and the white storks that follow the plough are all interesting examples of Albanian bird-life which presents forms typical of British ornithology, and others of Eastern Europe and the Mediterranean. The colony of pygmy cormorants at Lake Terbuf, the garganey and pintail of Lake Durazzo, where the yellow-legged herring-gull may be seen; six species of woodpeckers in the Mamuras woods and such interesting species as Cetti's warbler, Kentish plover, black-headed wagtail, Savi's warbler and the penduline tit at Lake Malik, and the rock thrush should provide ample material for observation if and when time is available.

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